Pathways to Adaptation and Resilience in South-East Asia

SUBREGIONAL REPORT

Asia-Pacific Disaster Report 2022 for ESCAP Subregions

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About the report

Resilience in a Riskier World: Managing Systemic Risks from Biological and Other Natural Hazards, the Asia Pacific Disaster Report 2021 captured a comprehensive picture of the complexity of disaster risk landscape ('riskscape') from natural and biological hazards in the Asia-Pacific region. The full-length publication is available at https://www.unescap.org/kp/2021/asia-pacific-disaster-report-2021. Following the release of the APDR at the seventh session of the ESCAP inter-governmental Committee on Disaster Risk Reduction in August 2021, the report was customized for each of the five ESCAP subregions, namely East and North-East Asia, North and Central Asia, South-East Asia, South and South-West Asia and the Pacific. The current report highlights the key takeaways for South-East Asia.

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CHAPTER 1

The shifting contours of the South-East Asia disaster riskscape

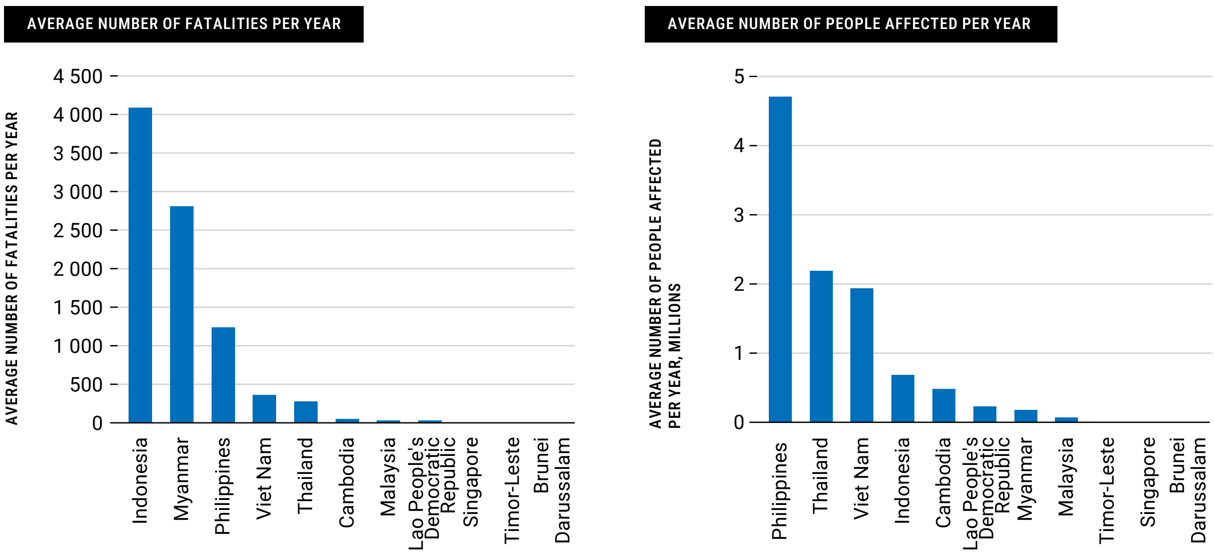
Highlights

- Climate change is reshaping and expanding the disaster riskscape in South-East Asia, increasing the risk of extreme weather events, such as typhoons, droughts and floods.
- In South-East Asia, the total average annual losses (AAL) from the disaster riskscape in the current condition is estimated to be $91 billion. This estimation increases to $108 billion under the moderate climate change scenario (RCP 4.5) and to $127 billion under the worst-case climate change scenario (RCP 8.5).
- South-East Asia faced an increased risk of cascading climate-related and vector-borne diseases, like dengue.

The disaster riskscape of South-East Asia

Over the past 50 years, close to 450,000 people have lost their lives and around 525 million people have suffered from natural hazards in South-East Asia. Between 1970 and 2021, Indonesia reported the largest fatalities with an average of approximately 4,100 fatalities each year, followed by Myanmar, with yearly average fatalities of around 2,800. The Philippines recorded the highest number of people affected per year, averaging around 4.7 million. This was followed by Thailand and Viet Nam, reporting a yearly average of close to 2.2 million and 2.0 million people affected, respectively (Figure 1-1).

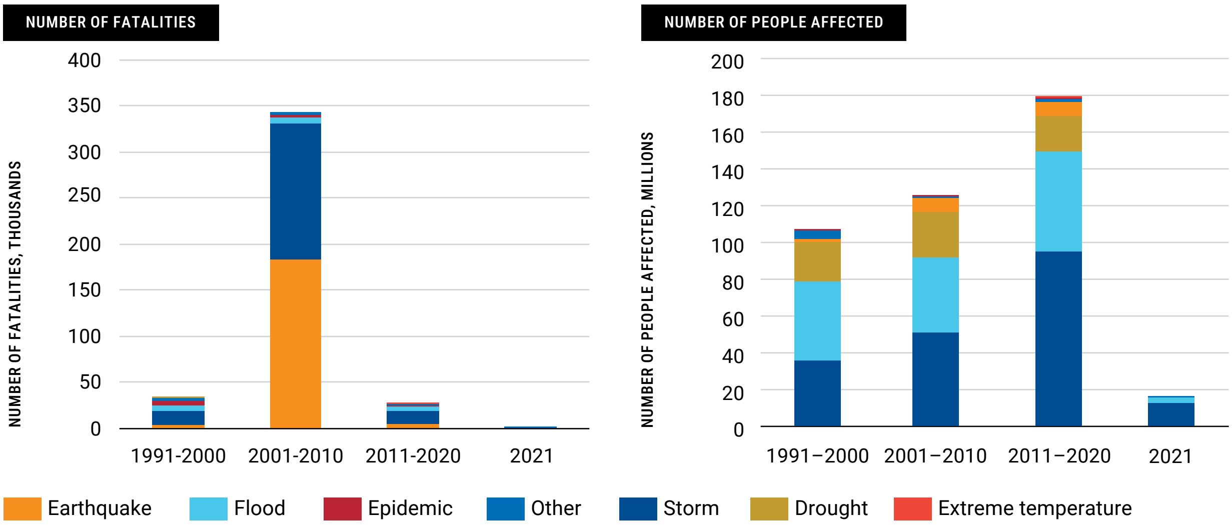
FIGURE 1-1 **Fatalities and people affected from natural hazards in South-East Asia, 1970–2021**



Data source: EM-DAT - The International Disaster Database. Available at http://www.emdat.be (accessed on 16 March 2022).

Extreme weather events, especially storms, floods and droughts, have been responsible for most people affected in South-East Asia (Figure 1-2). Since 2010, storms and floods have affected nearly 108 million and 57 million people, respectively, and storms caused the largest number of deaths with around 14,000 fatalities. While there was some progress in the number of fatalities from natural hazards in the last decade, the number of people affected has continuously increased during the past three decades.

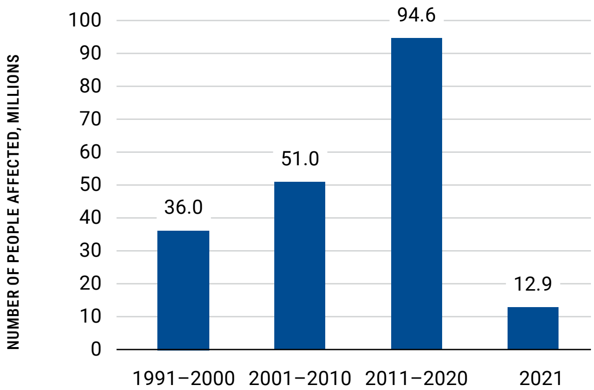
FIGURE 1-2 Number of fatalities and people affected by natural hazards in South-East Asia



Data source: EM-DAT - The International Disaster Database. Available at http://www.emdat.be (accessed on 16 March 2022).

Climate change and disaster riskscape in South-East Asia

FIGURE 1-3 Number of people affected by storms, 1991–2021



Data source: EM-DAT - The International Disaster Database. Available at http://www.emdat.be (accessed on 16 March 2022).

Climate change is reshaping and expanding the disaster riskscape in South-East Asia, leading to increased intensity of extreme weather events, such as tropical cyclones, droughts and floods. While most climate model studies project little change in the number of tropical cyclones each year, it is reported that the proportion of severe tropical cyclones has increased, and it is likely to continue rising.[1] In the western North Pacific region, tropical cyclones with a maximum surface wind speed of more than 100 knots (or 185.2 km/hr) have become stronger between 1978 and 2018.[2] In line with this, in South-East Asia, the number of people affected by storms escalated from 36 million, in the 1990s, to 95 million in the last decade (Figure 1-3). Tropical cyclones often hit countries with devastating impacts. For instance, in October 2020, Typhoon Goni (Rolly) killed 31 people and affected 2 million people in the Philippines, and Typhoon Molave (Quinta) caused 31 fatalities and affected nearly 888,000 people in the Philippines and Viet Nam. Subsequently, Typhoon Vamco (Ulysses) recorded 111 fatalities and affected nearly 4 million people in the Philippines and Viet Nam in November.[3]

Droughts have also continued to affect millions of people in South-East Asia, and drought severity is likely to shift geographically. During the past 30 years, droughts have affected over 66 million people in South-East Asia. Cambodia, Thailand, and Viet Nam recorded the highest populations affected by droughts in the decades 1991–2000 and 2001–2010. Cambodia, Indonesia, the Lao People's Democratic Republic and Malaysia recorded a large number of people being affected by droughts in the most recent decade, 2011–2020. Severe drought events were reported during the El Niño years, and the droughts in 2015–2016

1 Thomas R. Knutson and others, "Climate change is probably increasing the intensity of tropical cyclones", ScienceBrief Review, March 2021. Available at https://sciencebrief.org/uploads/reviews/ScienceBrief_Review_CYCLONES_Mar2021.pdf.

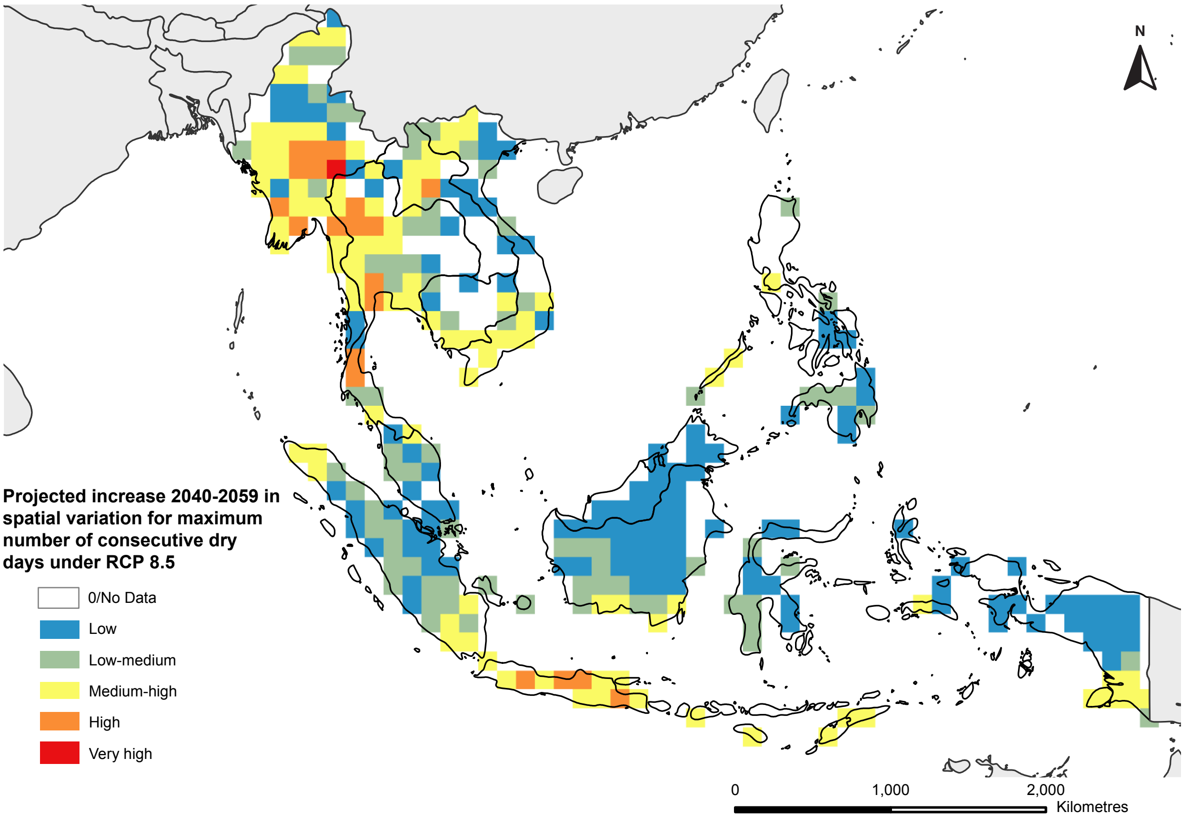
2 *Asia-Pacific Disaster Report 2021: Resilience in a Riskier World* (United Nations publication, 2021a).

3 EM-DAT - The International Disaster Database. Available at http://www.emdat.be.

and 2018–2020 were the most devastating events in the subregion since the drought in 1997–1998.[4] The drought event in 2015–2016, for example, affected nearly 2.5 million people in Cambodia, who suffered greatly from water shortages, land degradation, loss of livestock and reduced agricultural productivity. It also affected almost 250,000 hectares of cropland and destroyed over 40,000 hectares of rice.[5] In Malaysia, the drought contributed to the fires in Sabah that destroyed several hundred hectares of crops, causing water pollution and water scarcity in 10 villages.[6]

Climate change scenarios for the near and far future suggest that drought conditions are likely to become more severe in the region. The variation in rainfall pattern (anomaly) and projected higher temperatures will likely cause more frequent extreme dry conditions.[7] Figure 1-4 illustrates the projected maximum number of consecutive dry days for 2040–2059, under the worst-case scenario (RCP 8.5) in South-East Asia. It shows that large areas in Indonesia, Myanmar and Thailand are likely to experience a significant increase in the maximum number of consecutive dry days.

FIGURE 1-4 **Number of consecutive dry days – projected increase by 2040–2059**



Sources: Climate Change Knowledge Portal, 2018; and UN Geospatial.
Note: Projected Change 2040-2059 in Spatial Variation for Maximum Number of Consecutive Dry Days under RCP 8.5 ranges from 0 to maximum number of days.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

As noted in the 6th Assessment Report of IPCC, *Climate Change 2021: The Physical Science Basis*, **a warmer climate is also expected to intensify very wet weather, with monsoon precipitation projected to increase in the mid- to long-term, leading to flooding in South-East Asia.**[8] This is reflected in the significant increase

4 ASEAN Secretariat and ESCAP, "ASEAN Regional Plan of Action for Adaptation to Drought 2021–2025" (Jakarta, The ASEAN Secretariat, 2021). Available at https://www.unescap.org/kp/2021/asean-regional-plan-action-adaptation-drought-2021-2025.

5 *Ready for the Dry Years: Building resilience to drought in South-East Asia with a focus on Cambodia, Lao People's Democratic Republic, Myanmar and Viet Nam: 2020 Update* (United Nations publication, 2020b). Available at https://www.unescap.org/sites/default/files/publications/Ready%20for%20the%20Dry%20Years.pdf.

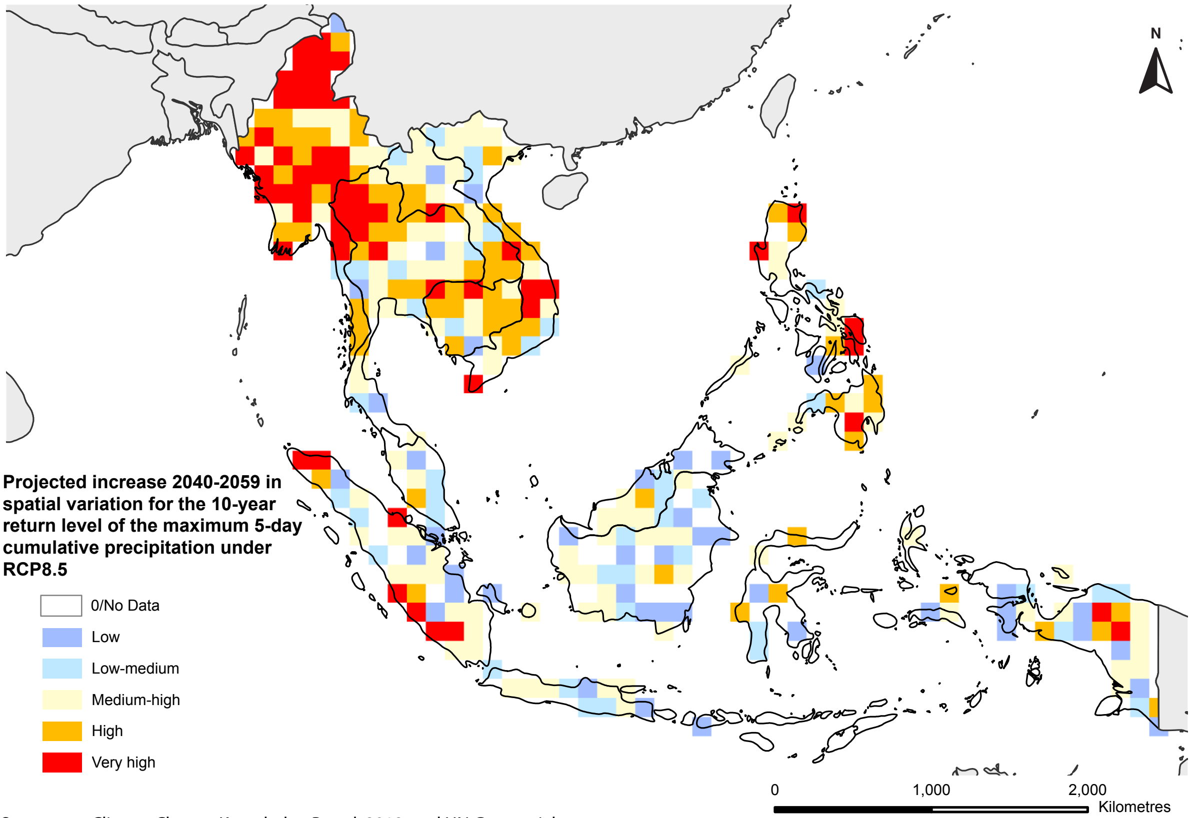
6 Ibid.

7 Ibid.

8 Intergovernmental Panel on Climate Change, "Climate Change 2021: The Physical Science Basis, Summary for Policymakers", Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2021. Available at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

in the number of people affected by floods in the past decade. In 2020, for instance, floods originating from heavy rains impacted more than 10 provinces in Thailand, causing 30 fatalities and affecting nearly 800,000 people.[9] Moreover, the maximum five-day cumulative precipitation is also expected to increase in several parts of the subregion, by 2040–2059, under the worst-case scenario (Figure 1-5). Although more rain in a short period (five days) does not necessarily lead to more flood events, it increases flood risks, especially in the flood-prone areas in South-East Asia. These risks are expected to rise in Myanmar, Thailand and several parts of other South-East Asian countries.

FIGURE 1-5 Maximum five-day cumulative precipitation, projected increase by 2040–2059



Sources: Climate Change Knowledge Portal, 2018; and UN Geospatial.
Note: Projected 2040-2059 in Spatial Variation for 10-year return level of the maximum 5-day cumulative Precipitation under RCP 8.5 ranges from 11mm to maximum precipitation amount.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

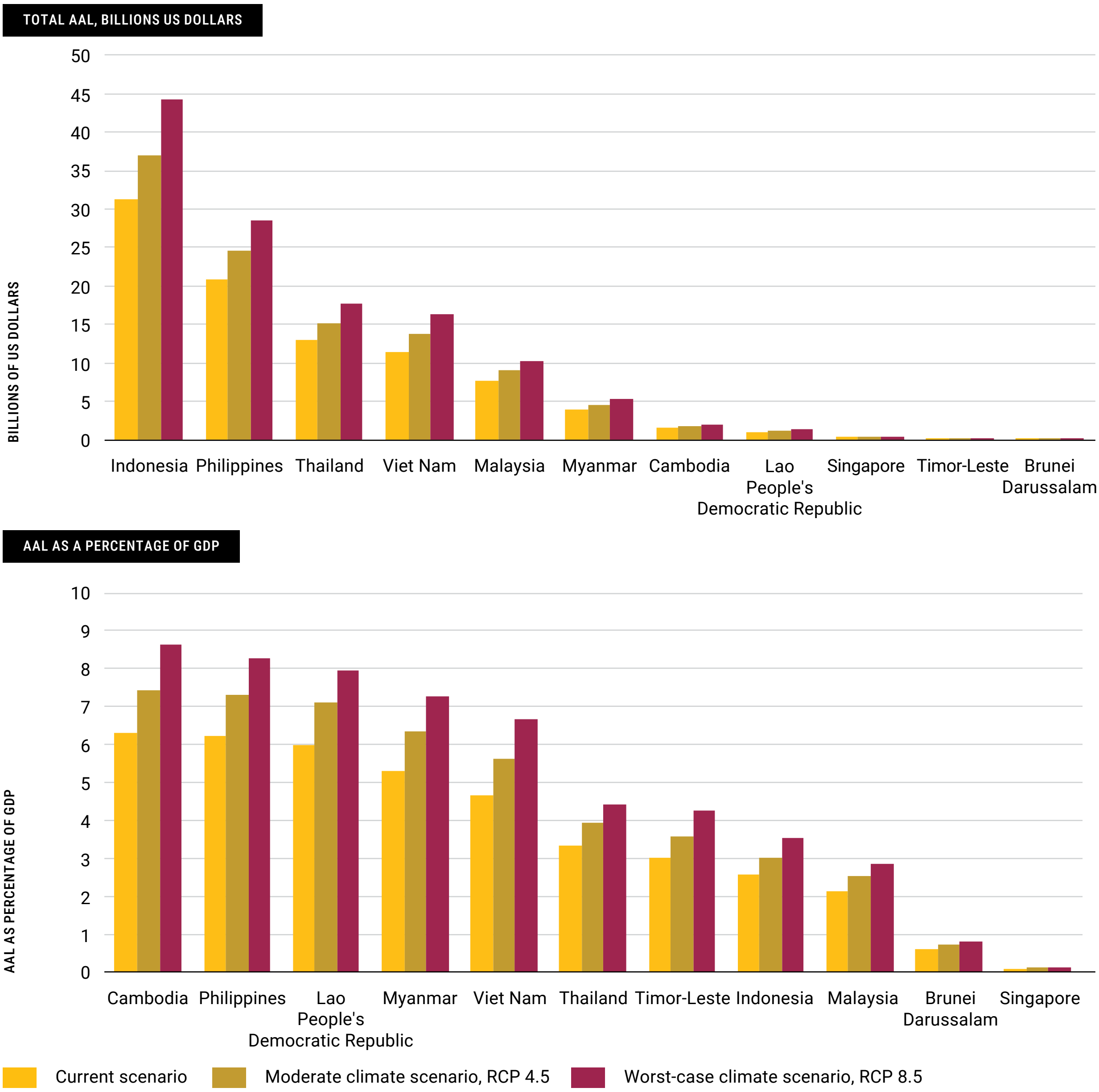
The economic cost of cascading hazards and climate change

ESCAP estimated the economic costs from the combined impacts of the disaster-climate-health nexus, considering two climate change scenarios. **In South-East Asia, the total average annual loss (AAL) is estimated at $91 billion in the current climate condition.[10] This estimation increases to $108 billion under the moderate climate change scenario (RCP 4.5), and to $127 billion under the worst-case climate change scenario (RCP 8.5).**

In absolute terms, under the worst-case scenario, Indonesia has the highest AAL at $44 billion, followed by the Philippines at $29 billion, and Thailand at $18 billion (Figure 1-6). However, the picture changes when assessed as a percentage of their respective GDPs. The Philippines has the highest AAL, as a percentage of GDP, at 8.6 per cent. This is followed by Cambodia and the Lao People's Democratic Republic, at 8.3 per cent and 8.0 per cent of GDP, respectively.

9 EM-DAT - The International Disaster Database. Available at http://www.emdat.be.
10 United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), "Risk and Resilience Portal". Available at https://rrp.unescap.org.

FIGURE 1-6 Total AAL and AAL as a percentage of GDP from cascading risks



Data source: ESCAP (2021) estimation based on the "Risk and Resilience Portal". Available at https://rrp.unescap.org.

A riskscape of cascading hazards

The convergence of biological and natural hazards with climate change has added to the risks of climate-related disasters in South-East Asia. Increasing frequency, intensity and unpredictability of extreme weather events are already affecting vulnerable sectors and communities, and cascading hazards are creating systemic risks that require more sustained and rigorous approaches.[11] Table 1-1 provides a snapshot of how climate change could alter the geography and intensity of natural and biological hazards and increase their combined impacts in South-East Asian countries. These risks are already identified in the Sendai Framework for Disaster Risk Reduction 2015–2030, as the framework recognized the central importance of health threats, including biological hazards.[12] The ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme 2021–2025 also envisions inter-

11 United Nations Office for Disaster Risk Reduction (UNDRR), "Integrating Disaster Risk Reduction and Climate Change Adaption in the UN Sustainable Development Cooperation Framework", Geneva, 2020a. Available at https://www.undrr.org/publication/integrating-disaster-risk-reduction-and-climate-change-adaptation-un-sustainable.

12 Natalie Wright and others, "Health emergency and disaster risk management: Five years into implementation of the Sendai Framework", *International Journal of Disaster Risk Science*, vol. 11 (2020), pp. 206–217. Available at https://link.springer.com/article/10.1007/s13753-020-00274-x.

sectoral cooperation and new partnerships as an important measure to enhance the region's disaster risk reduction and disaster management capacities.[13] Thus, climate change is not only affecting related hazards, but also exacerbating interactions between biological and other hazards.

TABLE 1-1 Impacts of climate change on natural and other biological hazards in South-East Asia

		CLIMATE CHANGE RISK	RELATED BIOLOGICAL AND HEALTH RISKS
South-East Asia	Indonesia	Increase in sea level risk and flooding	Increase of more than 50 million of population exposed to sea level rise
	Philippines	Increase in heatwaves	Increase in excess death due to heatwaves by 1%
		Increase in sea level risk and flooding	Increase of more than 50 million of population exposed to sea level rise
	Thailand	Increase in heatwaves	Increase in excess death due to heatwaves by 1.9%
	Viet Nam	Increase in heatwaves	Increase in excess death due to heat by 1.4%
		Increase in precipitation and flooding	Increase of more than 50 million of population exposed to sea level rise

Source: *Asia-Pacific Disaster Report 2021: Resilience in a Riskier World* (United Nations publication, 2021a).

In South-East Asia, there has been an increase in the risk of climate-related diseases in recent years. For vector-borne diseases, such as malaria and dengue, rising temperatures can reduce the incubation period of mosquitoes and facilitate the transmission of diseases.[14] Between 1990 and 2018, there was an increasing trend in the number of confirmed dengue cases in South-East Asia (Figure 1-7). In recent years, some of the highest cumulative dengue cases were recorded in the Philippines at 1.4 million confirmed cases, followed by Indonesia and Viet Nam (Figure 1-8).

In 2019, several countries in the subregion suffered from dengue outbreaks. In the Philippines, the Department of Health declared a national dengue epidemic, attributed to the 146,000 cases recorded from January to June 2019, almost double the number for the same period in 2018.[15] The Philippines also reported 25,500 confirmed dengue cases in 2020, including 38 deaths during the first five weeks only.[16] In Indonesia, even though the country has seen an overall decline in dengue cases and related deaths since 2016, 13,683 dengue fever cases were reported in 2019, and eight regions declared a dengue emergency.[17]

In the case of a Malaria outbreak, the total number of confirmed cases decreased from nearly 888,000 to 347,000, between 2007 and 2017. However, Indonesia and Myanmar still suffer from malaria, respectively reporting around 3.5 million malaria cases during this period.

13 ASEAN Secretariat, "ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme 2021–2025", (Jakarta, The ASEAN Secretariat, December 2020a). Available at https://asean.org/book/asean-agreement-on-disaster-management-and-emergency-response-aadmer-work-programme-2021–2025/.

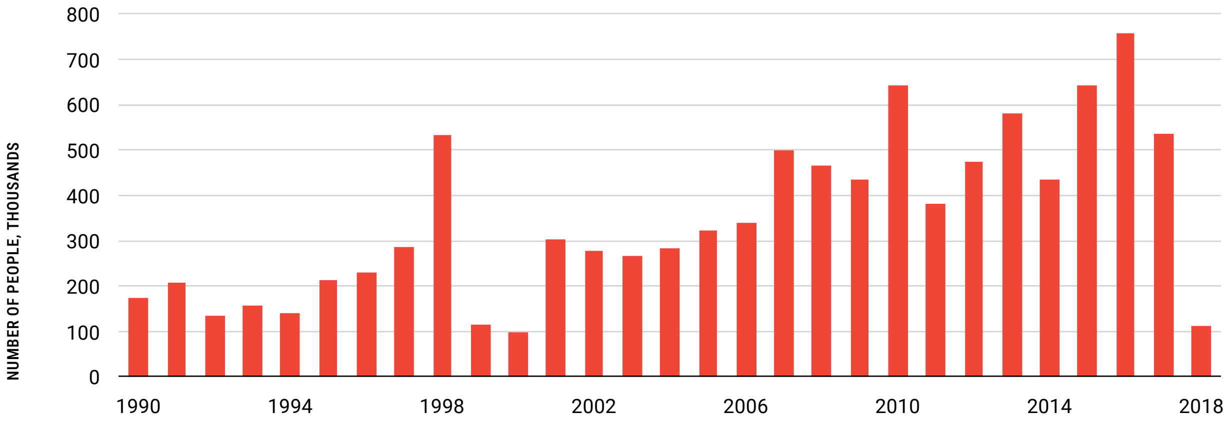
14 World Health Organization, "Climate change and human health – risks and responses", technical report, 4 December 2003. Available at https://www.who.int/publications/i/item/climate-change-and-human-health---risks-and-responses.

15 Government of the Philippines, Department of Health, "DOH declares national dengue epidemic", press release, 6 August 2019. Available at https://doh.gov.ph/press-release/DOH-DECLARES-NATIONAL-DENGUE-EPIDEMIC.

16 International Federation of Red Cross and Red Crescent Societies (IFRC), "Operation Update Report: Philippines: Re-emergence of Vaccine Preventable Diseases (polio)", 2020b. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/MDRPH032_12m.pdf.

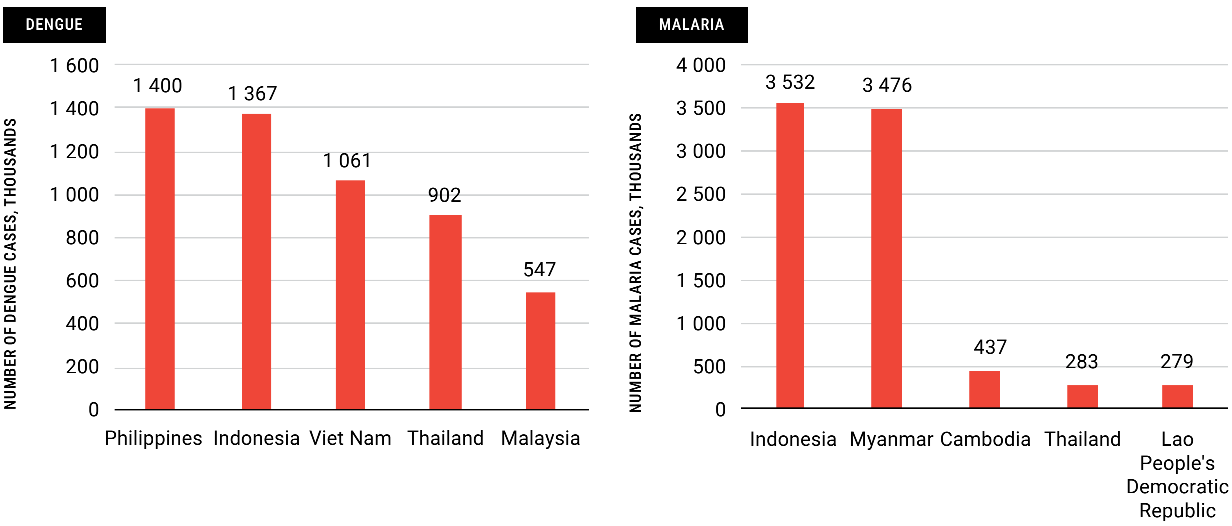
17 Gemma H. Cahya, "Dengue death toll climbs to 132, eight regions declare emergency", *The Jakarta Post*, 31 January 2019. Available at https://www.thejakartapost.com/news/2019/01/31/dengue-death-toll-climbs-to-132-eight-regions-declare-emergency.html.

FIGURE 1-7 Confirmed dengue cases in South-East Asia, 1990–2018



Source: World Health Organization, "Dengue Data Application". Available at https://ntdhq.shinyapps.io/dengue5/ (accessed on 6 Feb 2021).

FIGURE 1-8 Confirmed dengue and malaria cases in South-East Asian countries, 2007–2017



Data source: World Health Organization, "Dengue Data Application". Available at https://ntdhq.shinyapps.io/dengue5/ (accessed on 6 Feb 2021).

In South-East Asia, the convergence of natural hazards, like floods, tropical cyclones and droughts, with biological hazards brings forth a cascading risk scenario. The COVID-19 pandemic demonstrated this convergence of natural and biological hazards. It has revealed the cracks in the interdependent economic and social systems.

CHAPTER 2

Disasters during a global pandemic

Highlights:

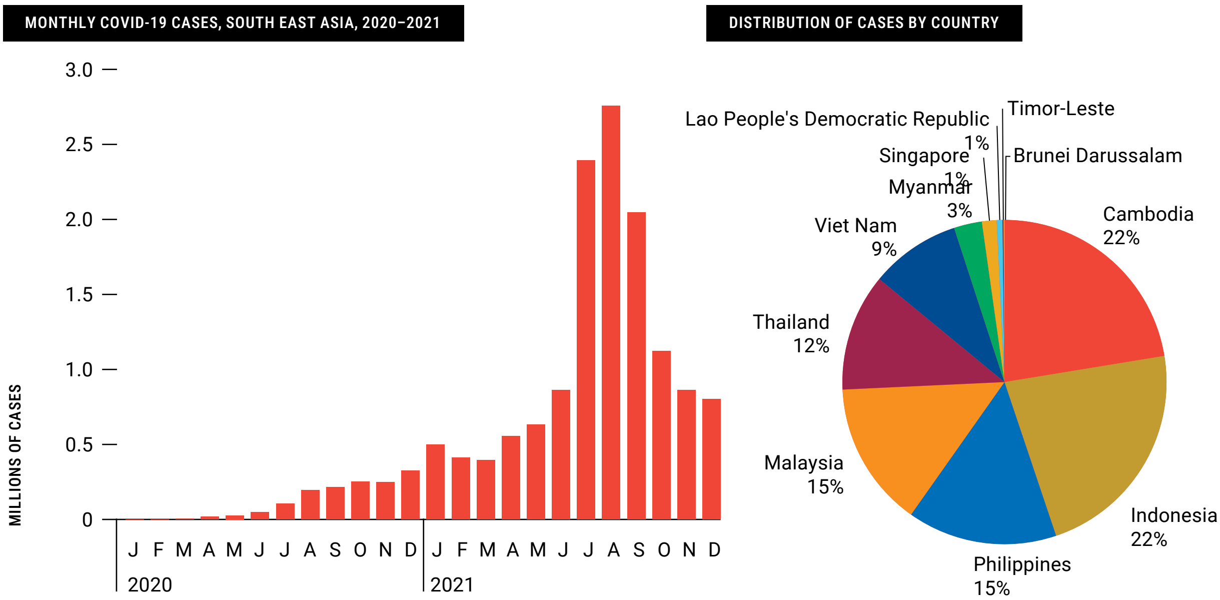
- In South-East Asia, countries faced the dual challenge of coping with the pandemic and natural hazards, especially typhoons and floods.
- South-East Asia is likely to face a more complex set of hazards arising from the nexus of climate change and related biological hazards.

COVID-19-compounded disasters

In South-East Asia, like other subregions in Asia and the Pacific, countries faced the dual challenge of addressing the COVID-19 pandemic and managing natural hazards. Impacts of biological hazards were compounded by other hazards, like tropical cyclones and floods, making it more difficult to respond effectively. Until December 2021, the pandemic had significantly impacted South-East Asia, with 19 million confirmed cases, with the highest cumulative cases reported in Cambodia, followed by Indonesia and the Philippines (Figure 2-1).[18]

While the COVID-19 pandemic raged on, the region continued to experience other natural hazards, many of which were hydro-meteorological (Figure 2-2). Nearly 15.7 million people were affected by natural hazards in South-East Asia in 2020. For instance, in the Philippines, Typhoon Vamco hit in October-November 2020, and affected 4.9 million people and caused 111 fatalities, and Typhoon Goni affected 2 million people, and caused 399 fatalities. Significant damage was also brought to the country's economy, with damages amounting to $42 million for Typhoon Vamco, and $369 million for Typhoon Goni. These events intersected with a period of high COVID-19 transmission in the Philippines, impeding recovery efforts. Similarly, Viet Nam was hit by Tropical Storm Linfa, in October 2020 during the pandemic, causing damages of $670 million.[19]

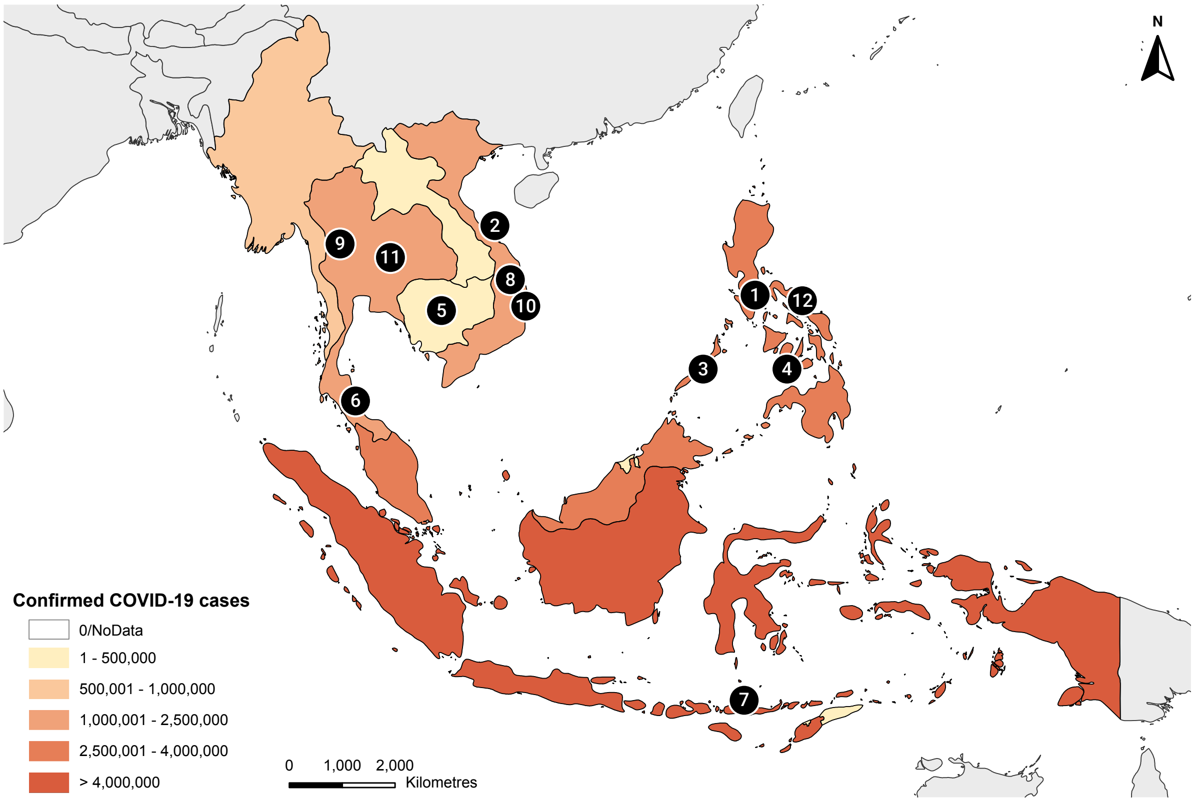
FIGURE 2-1 Monthly COVID-19 cases in South-East Asia, January 2020–December 2021



Data source: World Health Organization (WHO), "WHO Coronavirus (COVID-19) Dashboard". Available at https://covid19.who.int.

18 World Health Organization (WHO), "WHO Coronavirus (COVID-19) Dashboard". Available at https://covid19.who.int (accessed on 22 March 2022).
19 EM-DAT – The International Disaster Database. Available at http://www.emdat.be (accessed on 10 March 2022).

FIGURE 2-2 Convergence of COVID-19 with natural hazards in South-East Asia in 2020 and 2021



1 PHILIPPINES

Hazard: Typhoon 'Goni' (Rolly)
Period: 31 October–1 November 2020
Affected Population: 3 million
Damage in US $: 503 million

2 VIET NAM

Hazard: Tropical storm 'Linfa'
Period: October 2020
Affected Population: 2 million
Damage in US $: 850 million

3 PHILIPPINES

Hazard: Tropical cyclone 'Kompasu'
Period: 11 October–12 October 2021
Affected Population: 1 million
Damage in US $: 103 million

4 PHILIPPINES

Hazard: Typhoon 'Molave'
Period: 28 October 2020
Affected Population: 888 thousand
Damage in US $: 87 million

5 CAMBODIA

Hazard: Tropical storm 'Linfa'
Period: October 2020
Affected Population: 359 thousand
Damage in US $: 100 million

6 THAILAND

Hazard: Flash flood
Period: November–December 2020
Affected Population: 629 thousand
Damage in US $: 50 million

7 INDONESIA

Hazard: Tropical cyclone 'Seroja–21'
Period: 2 April–6 April 2021
Affected Population: 510 thousand
Damage in US $: 240 million

8 PHILIPPINES

Hazard: Typhoon 'Molave'
Period: 29 October 2020
Affected Population: 450 thousand
Damage in US $: 540 million

9 THAILAND

Hazard: Flood
Period: 27 August–31 August 2021
Affected Population: 325 thousand

10 VIET NAM

Hazard: Flood
Period: 27 November–30 November 2021
Affected Population: 300 thousand

11 THAILAND

Hazard: Flood
Period: 19 September–6 October 2021
Affected Population: 299 thousand

12 PHILIPPINES

Hazard: Flood
Period: 15 June–30 September 2020
Affected Population: 5.45 million
Damage in US $: 500 thousand

Source: ESCAP, based on World Health Organization (WHO), "WHO Coronavirus (COVID-19) Dashboard". Available at: https://covid19.who.int (accessed 21 December 2021); EM-DAT – The International Disaster Database. Available at: http://www.emdat.be (accessed 4 May 2021) and Reliefweb. Available at https://reliefweb.int (accessed February 2021).
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Responses to disasters during the COVID-19 pandemic

The lockdowns, travel restrictions and other containment measures enforced in response to COVID-19 interrupted many established measures for prevention, response, and recovery from natural hazards. At the same time, natural hazards also hampered the response to COVID-19 and facilitated the spread of the virus as people were forced to crowd together in emergency shelters.

TYPHOONS IN THE PHILIPPINES

In December 2021, the devastating Typhoon Rai (Odette) hit 11 out of 17 provinces including some of the poorest areas in the Philippines, affecting nearly 10 million people amid the pandemic.[20] The typhoon not only aggravated the risk of COVID-19 with disruptions like the Government pausing the vaccination drive,[21] but it also brought in water-borne diseases multiplying the health risk.[22] Further, Typhoon Goni (Rolly) made landfall in the Bicol region, in November 2020, which resulted in crowded evacuation centres and triggered a greater risk of COVID-19 transmission. The typhoon cut-off several towns from receiving adequate health-care services and damaged a main COVID-19 laboratory, resulting in the suspension of COVID-19 testing.[23] Typhoon Vongfong (Ambo) also hit the Philippines, in May 2020, amidst the COVID-19 outbreak, forcing the Government and other authorities to face dual challenges. The typhoon affected around 383,000 people across eight provinces and damaged nearly 60,000 houses.[24] While 27 hospital facilities also reported damages, the typhoon also destroyed multiple tent extensions in parking areas built to serve as COVID-19 hospitals.[25] As approximately 3,455 people took temporary shelter in 66 evacuation camps, it became difficult for the Government and local authorities to maintain social distancing.[26]

In response, authorities ordered that evacuation camps be filled to only half capacity. Other organizations, such as the Catholic Church, offered to use churches and chapels as additional shelter spaces.[27] Further, local officials were instructed to use alternative facilities as evacuation centres to better monitor and observe all health protocols. Authorities also promoted the ‘minimum health standards’, including physical distancing and frequent handwashing.[28]

FLOODS IN MALAYSIA AND INDONESIA

East Malaysia was faced with a monsoon flood in November 2020, affecting more than 48,000 people until January 2021. The flood caused major displacement and consequent overcrowding in relief centres, increasing the risks posed by the pandemic. Further, the shortage of clean water supplies during the floods also led to an increase in water-borne diseases, overburdening the health systems.[29] In Indonesia, multiple floods, in 2020, affected nearly 231 million people, especially in Jakarta, Aceh, Java, Sumatra, and the Sulawesi provinces.[30] For instance, floods in June 2020 caused $2.1 million in damages and affected

20 United Nations News, “Philippines: More support needed for thousands still reeling from Typhoon Rai”, 2 February 2022. Available at https://news.un.org/en/story/2022/02/1111142.

21 Ian Livingston, and Regine Cabato, “Super Typhoon Rai slams the Philippines after rapidly intensifying to a Category 5”, *The Washington Post*, 16 December. Available at https://www.washingtonpost.com/weather/2021/12/16/rai-philippines-typhoon-super.

22 International Federation of Red Cross and Red Crescent Societies (IFRC), “Philippines: Mounting health crisis after super typhoon”, 6 January 2022. Available at https://www.ifrc.org/press-release/philippines-mounting-health-crisis-after-super-typhoon.

23 United Nations News, “‘Super typhoon’ Goni: Towns cut off as COVID-19 impacts response”, 3 November 2020a. Available at https://news.un.org/en/story/2020/11/1076742 (accessed on 13 February 2021).

24 Government of the Philippines, Disaster Response Operations Monitoring and Information Center (DROMIC), “DSWD-DROMIC Report #28 on Typhoon “Ambo” as of 11 June 2020 6PM”, Situation Report, 13 June 2020. Available at https://reliefweb.int/report/philippines/dswd-dromic-report-28-typhoon-ambo-11-june-2020-6pm.

25 United Nations News, “Philippines typhoon recovery, complicated by coronavirus concerns”, 15 May 2020b. Available at https://news.un.org/en/story/2020/05/1064202.

26 Government of the Philippines, Disaster Response Operations Monitoring and Information Center (DROMIC), “DSWD-DROMIC Report #28 on Typhoon “Ambo” as of 11 June 2020 6PM”, Situation Report, 13 June 2020. Available at https://reliefweb.int/report/philippines/dswd-dromic-report-28-typhoon-ambo-11-june-2020-6pm.

27 Don Eliseo Lucero-Prisno III, and others, “Philippines braces for the typhoon season amidst COVID-19”, *The Lancet Regional Health – Western Pacific 1, Elsevier.* Available at https://www.thelancet.com/action/showPdf?pii=S2666-6065%2820%2930003-1.

28 Ibid.

29 Yuki Julius Ng, and others, “Floods amidst COVID-19 in Malaysia: Implications on the pandemic responses”, *Disaster Med Public Health Prep* (23 December 2021). Available at https://pubmed.ncbi.nlm.nih.gov/34937606/.

30 EM-DAT – The International Disaster Database. Available at http://www.emdat.be (accessed on 10 March 2022).

nearly 12,000 people on the Sulawesi Island.[31] Floodwaters also inundated critical infrastructures, such as hospitals and commuter lines. The convergence of floods with the COVID-19 pandemic disrupted the traditional ways of supporting vulnerable communities.[32]

To mitigate the impacts of flooding, some specific measures were implemented including donning protective equipment, applying decontaminants, maintaining a safe distance, and taking a swab test after rescue operations. Extra teams were also deployed to disperse crowds. In addition, the regional disaster management authorities took additional measures to address the dual challenge, like allocating separate rooms to flood victims who tested positive for COVID-19.[33]

VOLCANIC ERUPTION IN INDONESIA

In Indonesia, the Centre of Volcanology and Geological Hazard Mitigation (*Pusat Vulkanologi dan Mitigasi Bencana Geologi*, PVMBG) estimates more than 5 million people live in the 'danger zone' from volcanoes and must be evacuated in case of rising volcanic activity.[34] On 4 December 2021, the Mount Semeru volcano, located in the East Java province of Indonesia, reported its largest eruption in recent history, producing a hot cloud avalanche with volcanic materials and heavy ashfall. As of 6 December 2021, 34 fatalities were reported, along with 5,205 people affected. The eruption also caused significant infrastructure damage, including 2,970 houses and 24 schools.[35] As Indonesia continues to combat the COVID-19 pandemic, doctors raised concern about the possibility of a rise in COVID-19 cases, or people experiencing more severe symptoms from ashes and volcanic debris.[36]

MORE COMPLEX HAZARDS AHEAD

As climate change intensifies and biological threats prevail, South-East Asia is likely to face an increasingly complex set of hazards. ESCAP estimates show that multi-hazard cascading risks alone can amount to losses worth 4.3 per cent of South-East Asia's regional GDP in the worst-case climate change scenario (RCP 8.5, 2020–2059 projection). Countries will need to take comprehensive action to protect all, especially the most vulnerable, by integrating health and disaster risk management into more robust health and social protection systems based on cascading risk scenarios. In this context, new instruments, like the ASEAN Comprehensive Recovery Framework (ACRF), provide recommendations on tackling the multi-dimensional impacts of the pandemic and on coordinated action for recovery.[37]

31 Ibid.

32 Yoko Okura, Piva Bell, and Iswar Abidin, Iswar, "Strengthening Resilience to Flood Vulnerable Communities in Indonesia During the COVID-19 Crisis", United Nations Office for Disaster Risk Reduction, Flood Resilience Portal, 27 May 2020. Available at https://www.preventionweb.net/news/strengthening-resilience-flood-vulnerable-communities-indonesia-during-covid-19-crisis.

33 Linda Yulisman, "Flood rescuers in Indonesia take precautions amid COVID-19 pandemic", *The Strait Times*, 16 February 2021. Available at https://www.straitstimes.com/asia/se-asia/flood-rescuers-in-indonesia-take-precautions-amid-covid-19-pandemic.

34 Center for Excellence in Disaster Management and Humanitarian Assistance (CFE-DM), "Indonesia: Disaster Management Reference Handbook", December 2021. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/CFE-DM-DMRH-Indonesia2020.pdf.

35 Reno Surya, and Aisyah Llewellyn, "COVID stalks Indonesian villagers who fled Semeru's burning ash", *Aljazeera*, 10 December 2021. Available at https://www.aljazeera.com/news/2021/12/10/indonesia-covid19-semeru-eruption.

36 Ibid.

37 ASEAN Secretariat, "ASEAN Comprehensive Recovery Framework" (Jakarta, 2020b). Available at https://asean.org/book/asean-comprehensive-recovery-framework/.

CHAPTER 3

Hotspots of exposure and vulnerability to climate-induced cascading risks

Highlights

- South-East Asia is witnessing intensifying and emerging hotspots of climate and related biological hazards, especially from tropical cyclones, droughts, floods and their associated biological diseases.
- Against the intensifying risk of cascading hazards, it is critical to identify vulnerable groups, including the poor, the elderly, children and women, and migrants and build their resilience.
- In building resilience, countries should also consider the levels of exposure and vulnerability of critical infrastructures, such as energy and health-care infrastructure, to multi-hazard risk.

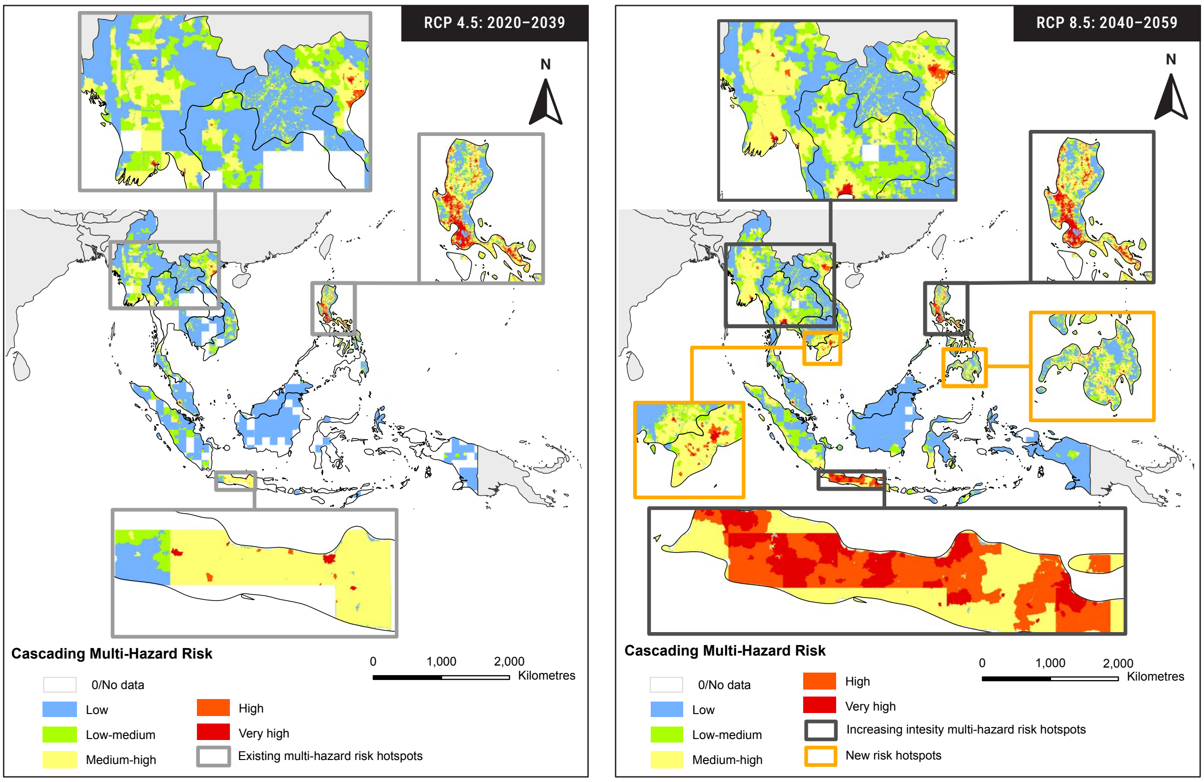
Climate change and expanding hotspots of cascading hazards

South-East Asia has several risk hotspots, mainly from floods, droughts, and tropical cyclones. With the changing climate variables, climate-related disasters are set to intensify and become more frequent. The areas already vulnerable to natural hazards face a more complex riskscape from changing climate conditions and associated risks from biological hazards.

Multi-hazard risks (from climate-related and biological hazards)

Hotspots of multi-hazard risks will intensify from the moderate to worst-case climate change scenarios in South-East Asia. For instance, the cascading multi-hazard risks will likely intensify in the worst-case scenario, and they are to be highest in parts of Indonesia, Myanmar, Thailand and Viet Nam (Figure 3-1).

FIGURE 3-1 **Multi-hazard risk hotspots from climate-related hazards and climate change under moderate (RCP 4.5) and worst-case (RCP 8.5) scenarios in South-East Asia, 2040–2059**



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; UN WPP-Adjusted Population Density 2020, v4.11; and Disability-Adjusted Life Years (DALYs) estimates 2000-2019; and UN Geospatial.

Note: Cascading Hazard Risk is obtained from multi-hazard file that consists of highest intensity of GAR Cyclone Wind within 100 year return period; Climate projection data for flood, drought and heatwaves under RCP 4.5 in 2020-2039 and under RCP 8.5 in 2040-2059 by Population and DALYs for related multi-hazard.

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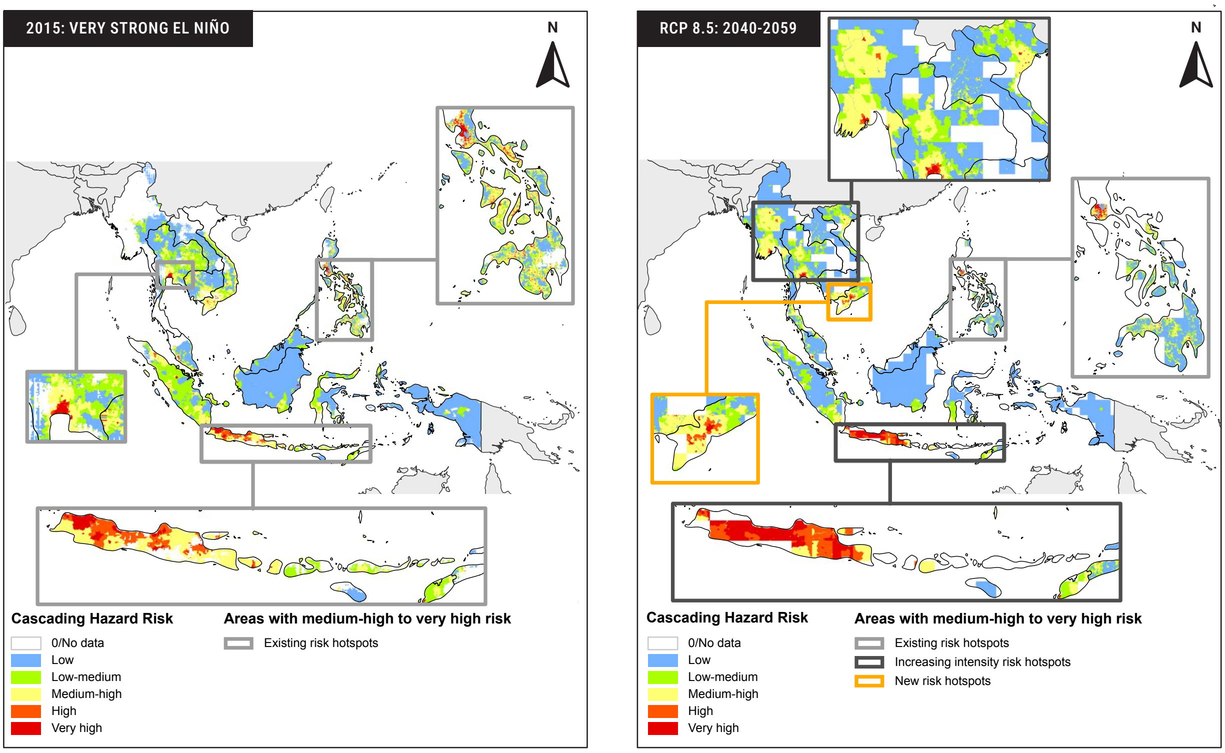
Flood and related diseases

While several areas in the Indo-China region are identified as hotspots of flood and related diseases, new hotspots are expected to emerge in the Philippines and Indonesia (Figure 3-2). The existing risk hotspots are also likely to be intensified. Here, the population exposure to floods and related diseases is projected to increase multi-fold in many countries under the worst-case climate change scenario. 185 million people (68.2 per cent of the population) in Indonesia, 68 million people (70 per cent of the population) in Viet Nam, and 68 million people (69.7 per cent of the population) in the Philippines are expected to be exposed to the cascading impacts of floods and related diseases (Figure 3-3).[38]

FIGURE 3-2 **Population exposure to flood and related diseases in South-East Asia under current and worst-case climate change scenario (RCP 8.5), 2040–2059**



Sources: ESCAP calculations, based on 6-months Standardized Precipitation Index (SPI6) of Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), 2015; Climate Change Knowledge Portal, 2018; UN WPP Adjusted Population Density 2020, v4.11; and Disability-Adjusted Life Years (DALYs) estimates 2000-2019; and UN Geospatial.

Notes: 1. Cascading Hazard Risk is obtained from spatial variation of SPI6 for 2015 and Projected Change in Spatial Variation for Maximum Number of Consecutinve Dry Days under RCP 8.5 by Population and Disability-Adjusted Life Years (DALYs).
2. The spatial variation of SPI6 ranges from - 0.8 to the minimum value (moderate to exceptional drought) and Projected change 2020-2039 and 2040-2059 in Spatial Variation for Maximum Number of Consecutive Dry Days under RCP 8.5 ranges from 0 to maximum number of days
3. DALY indicators for drought related diseases consist of nutritional and vitamin deficiencies.

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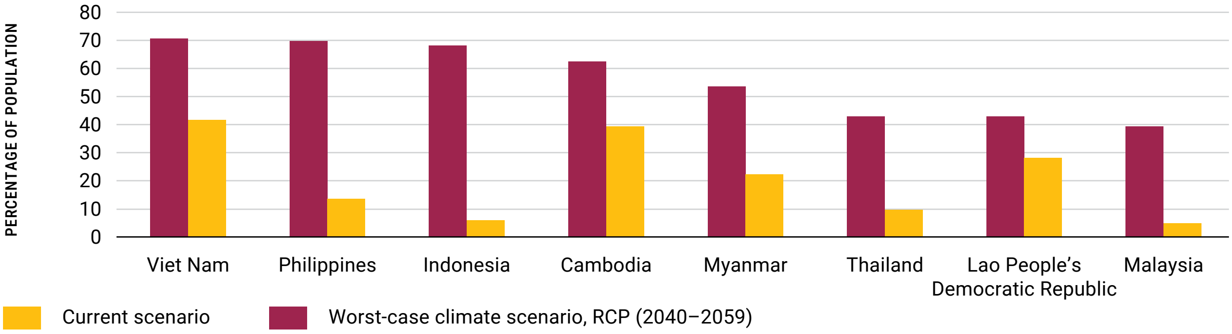
FIGURE 3-3 **Percentage of population exposed to the risk of floods and related diseases under current and worst-case (RCP 8.5) scenarios in South-East Asian countries**



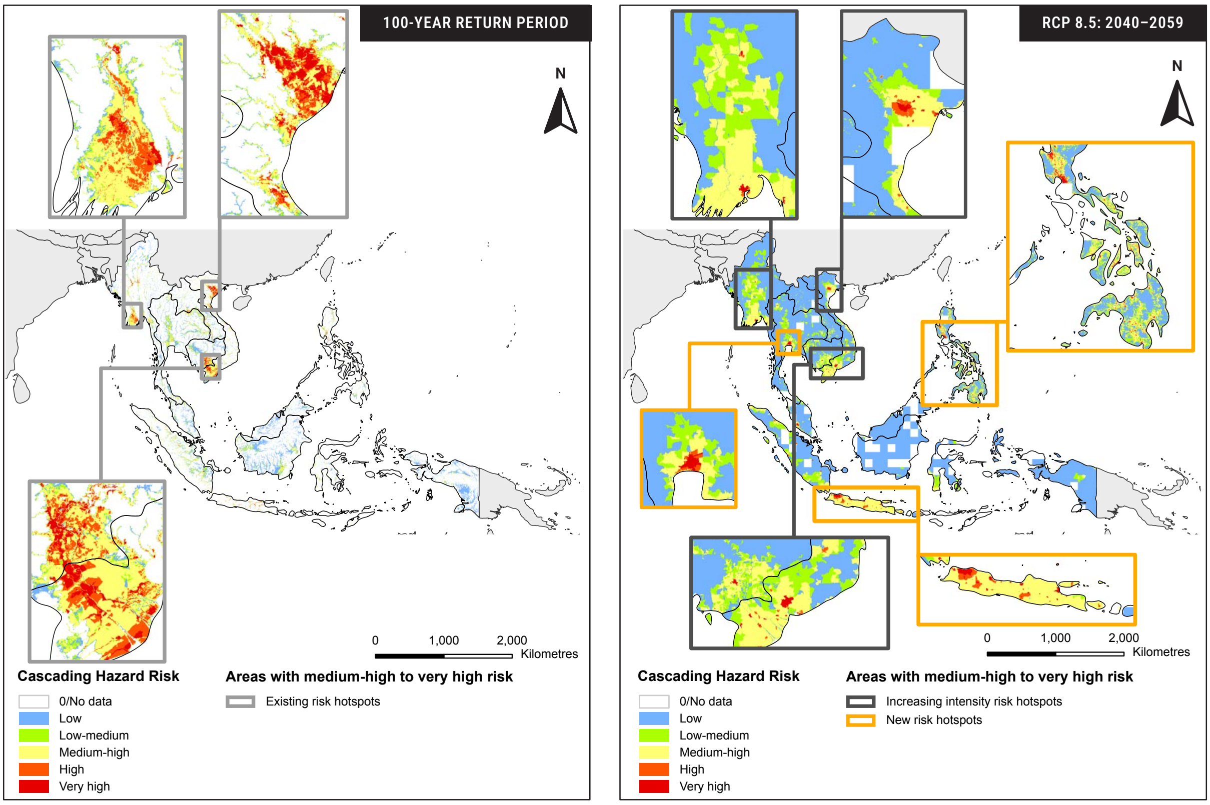
Sources: ESCAP calculations, based on World Bank, Climate Change Knowledge Portal, 2018; UN WPP-Adjusted Population Density 2020, v4.11; and Disability-Adjusted Life Years (DALYs) estimates 2000–2019.

38 United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), "Risk and Resilience Portal". Available at https://rrp.unescap.org.

Drought and related diseases

While droughts are responsible for the largest average annual losses in South-East Asia, hotspots of drought and related diseases are likely to expand. Under the worst-case scenario (2040–2059 projections), hotspots of drought and related diseases are expected to intensify in Indonesia, while new risk hotspots are likely to emerge in parts of Myanmar, Thailand and Viet Nam (Figure 3-4). In this scenario, the population exposed to medium-very high risk of drought and related hazards is expected to be nearly 329 million, or 50 per cent of the total population of the subregion. It is projected to be the highest in Cambodia, the Philippines and Brunei Darussalam (Figure 3-5).

FIGURE 3-4 **Hotspots of population exposure to drought and related diseases under current and worst-case climate change scenarios (RCP 8.5) in South-East Asia**



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; UN WPP Adjusted Population Density 2020, v4.11; and Disability-Adjusted Life Years (DALYs) estimates 2000-2019; and UN Geospatial.

Notes: 1. Cascading hazard risk is obtained from Flood hazards 100 years and Projected Change 2040-2059 in Spatial Variation for the 10-year return level of the maximum 5-day cumulative Precipitation under RCP 8.5 by population and Disability-Adjusted Life Years (DALYs).

2. Projected Change 2040-2059 in Spatial Variation for 10-year return level of the maximum 5-day cumulative Precipitation under RCP 8.5 ranges from 11mm to maximum precipitation amount.

3. DALY indicators for flood related diseases consist of diarrheal diseases, measles, hepatitis A, malaria, dengue and drowning.

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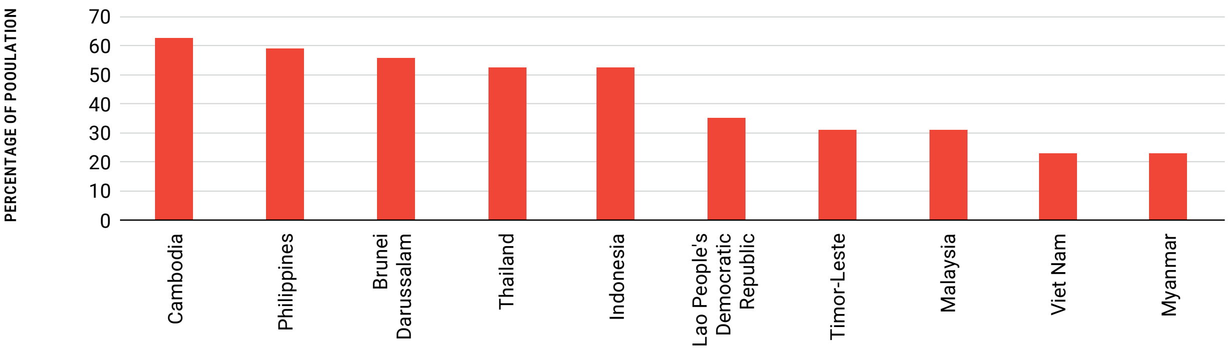
FIGURE 3-5 **Population exposure to medium-very high risk of drought and related diseases under worst-case (RCP 8.5) scenarios in South-East Asia**



Source: ESCAP calculations, based on World Bank, Climate Change Knowledge Portal, 2018; UN WPP-Adjusted Population Density 2020, v4.11; and Disability-Adjusted Life Years (DALYs) estimates 2000–2019.

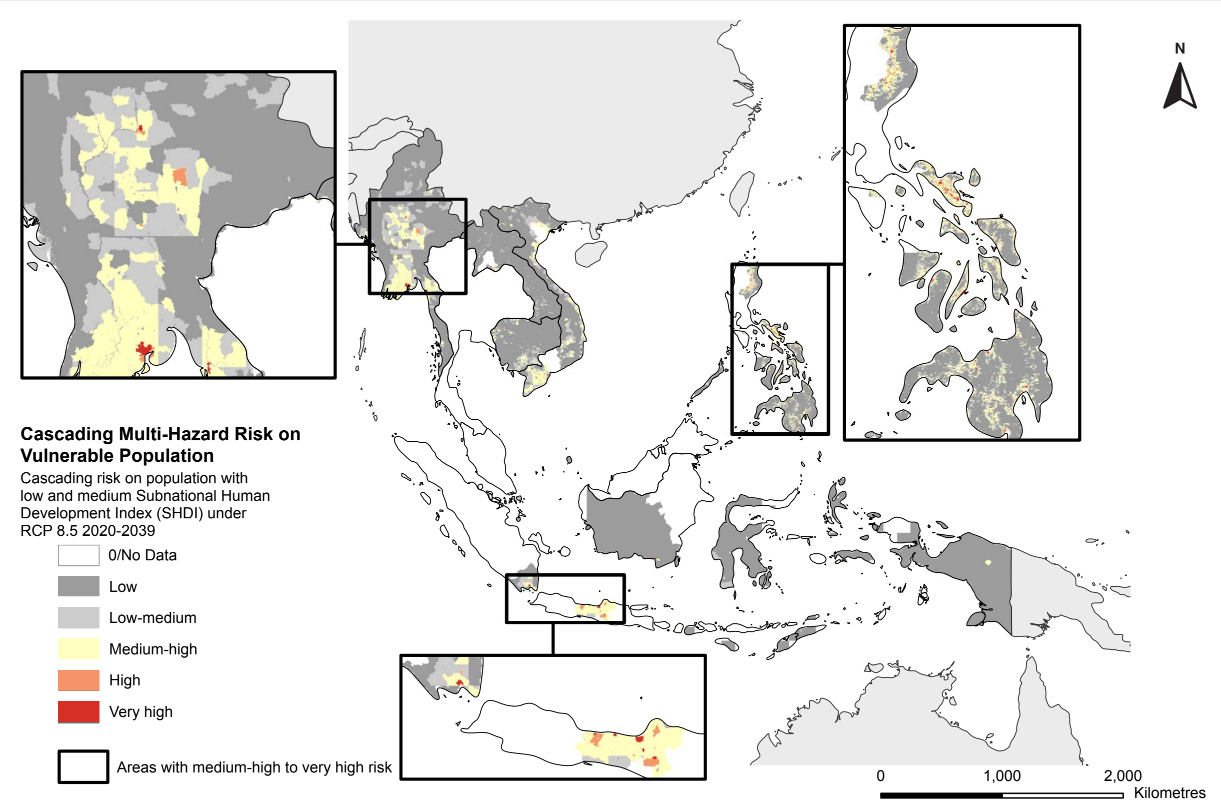
Identifying vulnerable groups to cascading hazards

Often, the most vulnerable populations face cascading multi-hazard risks, and climate change is expected to worsen this situation. Thus, one of the critical principles of disaster risk management is to identify the most vulnerable communities, protect them and build their resilience.

People with low levels of human development index

The capabilities of people to manage disaster risks can be broadly understood, among others, by the human development index (HDI), a summary measure of average achievement in key dimensions of human development. **The number of people with low and medium HDI and risk from cascading hazards is likely to increase substantially in South-East Asia (Figure 3-6).**

FIGURE 3-6 **Populations with lower levels of human development index at risk from cascading hazards under the worst-case climate change scenario (RCP8.5)**



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; Disability-Adjusted Life Years (DALYs) estimates 2000-2019; Sub-National Human Development Index (SHDI) Version 4.0, 2020 and UN WPP-Adjusted Population Density 2020, v4.11; and UN Geospatial.

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Table 3-1 indicates the proportion of the population with low and medium HDI exposed to multi-hazard cascading risks under moderate (RCP 4.5) and worst-case (RCP 8.5) climate change scenarios. In South-East Asia, Myanmar has the highest proportion of the population with low and medium HDI. Up to 50 per cent of the population is exposed to multi-hazard cascading risks under the worst-case scenario (2040–2059 projections). Other countries in South-East Asia that expect a large percentage of their population with low and medium HDI to be exposed to multi-hazard cascading risks, include the Lao People's Democratic Republic, the Philippines, and Viet Nam (30 per cent) and Cambodia (25 per cent).

TABLE 3-1 **Proportion of the population with low/medium HDI exposed to multi-hazard cascading risks in South-East Asian countries**

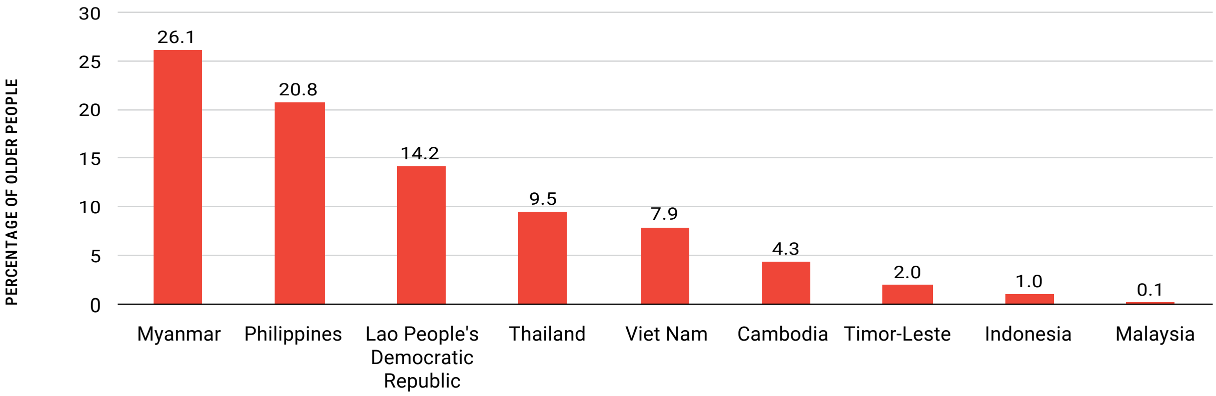
Subregion	Country	Timescale under climate change scenarios: Percentage of population with low/medium HDI under RCP 4.5 (2020–2039)	Percentage of population with low/medium HDI under RCP 4.5 (2040–2059)	Percentage of population with low/medium HDI under RCP 8.5 (2020–2039)	Percentage of population with low/medium HDI under RCP 8.5 (2040–2059)
South-East Asia	Cambodia	7	4	26	25
	Indonesia	7	15	14	15
	Lao People's Democratic Republic	14	23	26	30
	Myanmar	29	26	47	50
	Philippines	15	24	26	30
	Thailand	0.28	0.09	0.39	0.45
	Timor-Leste			18	8
	Viet Nam	12	23	25	30

Source: *Asia-Pacific Disaster Report 2021: Resilience in a Riskier World* (United Nations publication, 2021a).

Elderly populations

The elderly population can be at a greater risk, during disasters, due to the lack of mobility, accessibility and speed of evacuation. **Across South-East Asia, more than 448 million people aged above 70 are estimated to be at risk of cascading multi-hazards in the worst-case climate change scenario**. The highest proportions of the elderly population at risk are recorded in Myanmar, with more than one-fourth of the elderly population at risk of cascading multi-hazard risks. The Philippines and the Lao People's Democratic Republic are also expected to have a large percentage of their elderly population at risk, with around 21 per cent and 14 per cent, respectively (Figure 3-7).

FIGURE 3-7 **Percentage of older people (aged over 70) at risk of cascading multi-hazard risk under RCP 8.5**

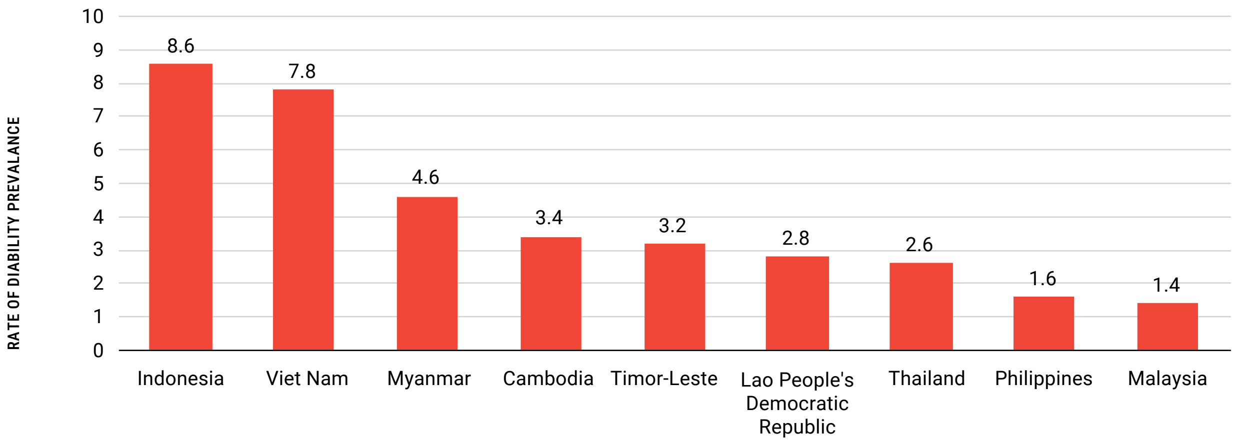


Sources: ESCAP based on Center for International Earth Science Information Network (CIESIN), Earth Institute, Columbia University, "Gridded Population of the World, Version 4.11 (GPWv4)", NASA Socioeconomic Data and Applications Center (SEDAC). Available at https://sedac.ciesin.columbia.edu/data/collection/gpw-v4/maps/gallery/search.

People with disabilities

People with disabilities are also vulnerable to disasters. In South-East Asia, the prevalence of disability is the highest in Indonesia at 8.6 per cent of the total population, followed by Viet Nam at 7.8 per cent of the population (Figure 3-8). These records highlight the importance of disability-inclusive disaster risk reduction (DRR) policy measures.

FIGURE 3-8 Rate of disability prevalence in South-East Asia, by country

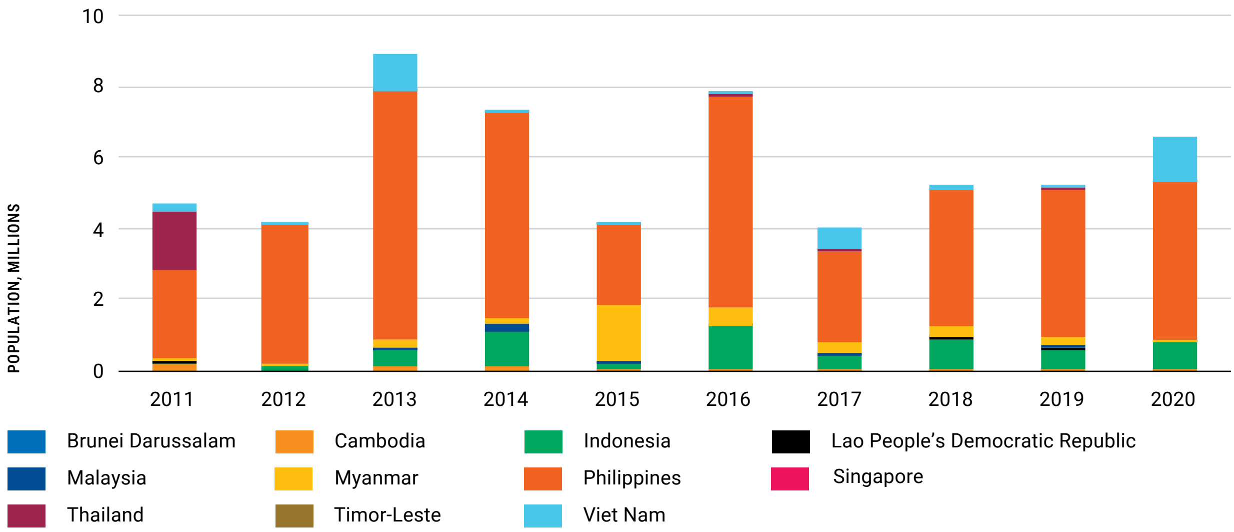


Source: Disability statistics taken from *Disability at a Glance 2019: Investing in Accessibility in Asia and the Pacific* (United Nations publication, 2019b). Available at https://www.unescap.org/publications/disability-glance-2019.

Displaced populations

In South-East Asia, natural hazards have triggered significant numbers of internal displacement. In the last decade, countries in the region reported almost 58 million people being displaced from natural hazards (Figure 3-9). Storms and floods were responsible for the displacement of 54.5 million people, or 94 per cent of the total displacement during this period. In the Philippines alone, there were 42.2 million displacements from disasters, while Indonesia (5.3 million people), Viet Nam (3.6 million people), Myanmar (3.5 million people) and Thailand (1.9 million people) also reported many displacements from natural hazards. More recently, South-East Asian countries reported 6.6 million people displaced from natural hazards in 2020.[39]

FIGURE 3-9 Internal displacement from natural hazards in South-East Asian countries, 2011–2020



Data source: Internal Displacement Monitoring Centre (IDMC), "2020 Internal Displacement", Global Internal Displacement Database. Available at https://www.internal-displacement.org/database/displacement-data (accessed in December 2021).

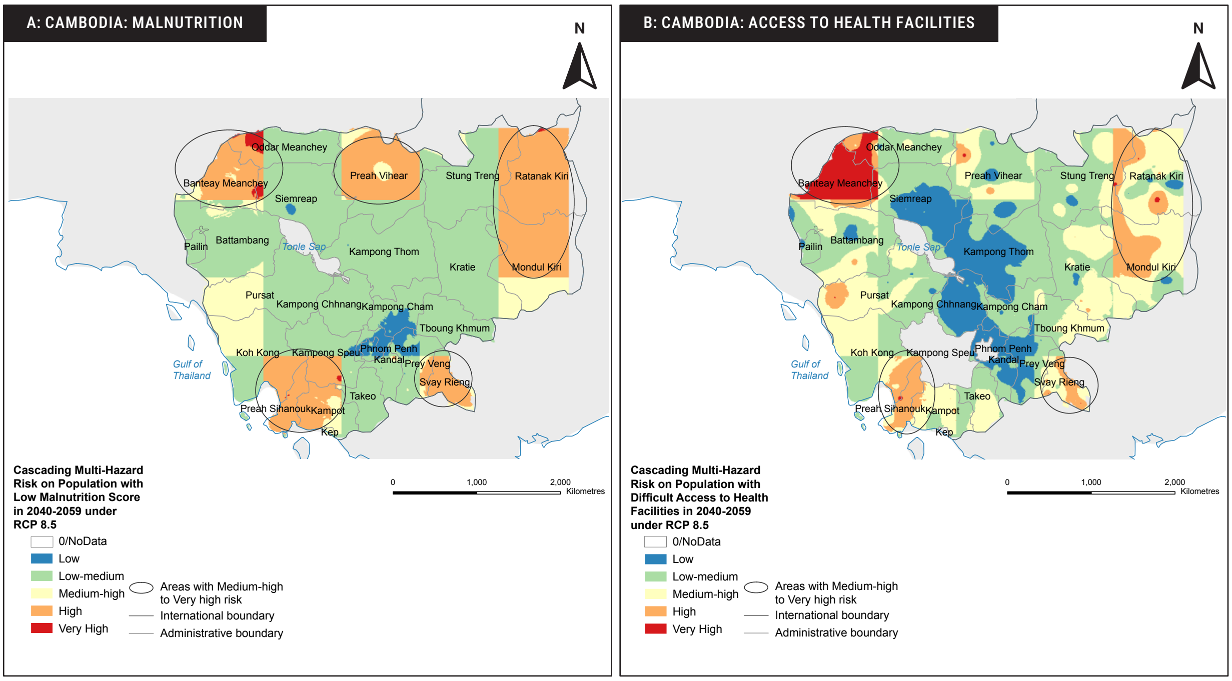
39 Internal Displacement Monitoring Centre (IDMC), "2020 Internal Displacement", Global Internal Displacement Database. Available at https://www.internal-displacement.org/database/displacement-data (accessed in December 2021).

Other vulnerable groups

When disasters strike, children, more than adults, can face a higher risk from inaccessibility to information and lack of adaptive capacity, while they are also prone to encounter violence, abuse, neglect and exploitation during a disaster.[40] Those exposed to meteorological hazards are more likely to have lower birth weights, die before the age of five, suffer from vector-borne diseases, or have fewer years of schooling.[41] In Cambodia, the children at highest risk of cascading hazards and malnutrition are located in Stung Treng in the north, Mondul Kiri, Ratanak Kiri in the east and around Svay Rieng Kampot and Koh Kong provinces in the south (Figure 3-10a). In these areas, it will be essential to ensure that critical infrastructure, such as hospitals, schools, and electricity grids, are resilient to the impacts of cascading hazards.

Natural hazards and climate change could also widen gender disparities by limiting access to health-care services.[42] In Cambodia, the risk is likely to be the greatest in the provinces of Bântéay Méanchey and Otdar Mean Chey in the north (Figure 3-10b).

FIGURE 3-10 **Population exposed to cascading multi-hazard risks; malnutrition and limited access to healthcare, under the worst-case climate change scenario, in Cambodia**



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; Disability-adjusted Life Years (DALYs) estimates 2000-2019; Demographic and Health Surveys (DHS) Programme for Cambodia, 2014; and UN Geospatial.

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40 International Federation of Red Cross and Red Crescent Societies, "Come heat or high water: Tacking the humanitarian impacts of the climate crises together", World Disasters Report 2020 (Geneva, 2020a). Available at https://reliefweb.int/report/world/world-disasters-report-2020-come-heat-or-high-water-tackling-humanitarian-impacts.

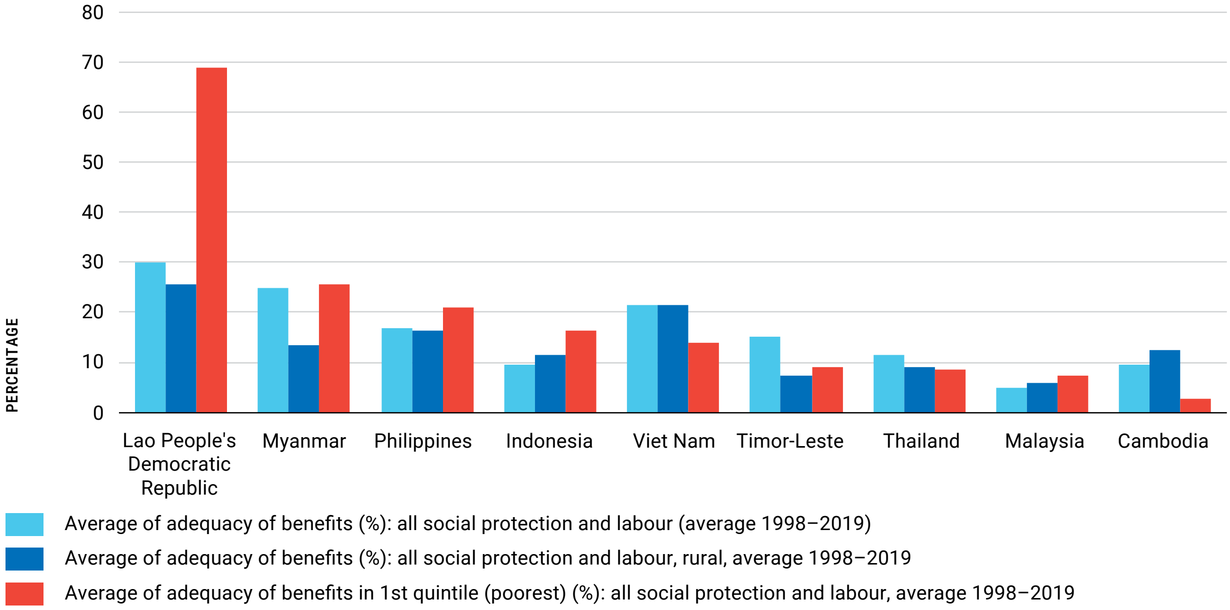
41 *Asia-Pacific Disaster Report 2019: The Disaster Riskscape across Asia-Pacific* (United Nations publication, 2019a). Available at https://www.unescap.org/sites/default/files/publications/Asia-Pacific%20Disaster%20Report%202019_full%20version.pdf.

42 Cecilia Sorensen and others, "Climate change and women's health: Impacts and policy directions", *PLOS Medicine*, vol. 15, No. 7 (10 July 2018). Available at https://doi.org/10.1371/journal.pmed.1002603.

Disaster responsive social protection is critical to building resilience

Although the inclusion of vulnerable groups in disaster risk reduction strategies is vital to ensure the inclusiveness of disaster responses, it is equally essential for countries to ensure that vulnerable groups have sound social protection; before, during and after disasters hit. Countries in South-East Asia have made efforts to ensure that their people are well-protected. For instance, the *ASEAN Guidelines on Disaster Responsive Social Protection to Increase Resilience* shows the way forward in the region, for utilizing responsive social protection to achieve lasting and inclusive development.[43] At the country level, in the Lao People's Democratic Republic, Myanmar, the Philippines and Viet Nam, the average adequacy of all social protection offered to the poorest quintile is higher than the average for the entire population, signalling that sufficient social protection has been targeted to this vulnerable group. Nevertheless, gaps remain in providing adequate social protection especially for the rural population (Figure 3-11).

FIGURE 3-11 **Social protection for vulnerable groups in selected South-East Asian countries**



Source: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015.
Note: Adequacy of Benefits is the "Total transfer amount received by all beneficiaries in a population group as a share of the total welfare of beneficiaries in that group", as defined in The World Bank, "The Atlas of Social Protection Indicators of Resilience and Equity". Available at https://databank.worldbank.org/source/the-atlas-of-social-protection:-indicators-of-resilience-and-equity.

Identifying critical infrastructure at risk

Natural hazards can have devastating impacts on critical infrastructure, and disaster relief could be delayed with prolonged economic disruptions.[44] For instance, in Indonesia, floods caused by heavy rains damaged nine bridges along with roads, houses and schools in November 2021.[45] During Typhoon Vamco, that hit Viet Nam in 2020, airports in multiple cities stopped operations as a precaution.[46] The resulting delays in service delivery and access to critical infrastructure can have differential impact on the poor who often live in marginal areas. Climate change can amplify these existing vulnerabilities.

43 ASEAN Secretariat, "ASEAN Guidelines on Disaster Responsive Social Protection to Increase Resilience" (Jakarta, The ASEAN Secretariat, 2021b). Available at https://asean.org/book/asean-guidelines-on-disaster-responsive-social-protection-to-increase-resilience/.

44 *The Economic and Social Survey of Asia and the Pacific 2021: Towards post-COVID-19 resilient economies* (United Nations publication, 2021b). Available at https://www.unescap.org/kp/2021/economic-and-social-survey-asia-and-pacific-2021-towards-post-covid-19-resilient-economies.

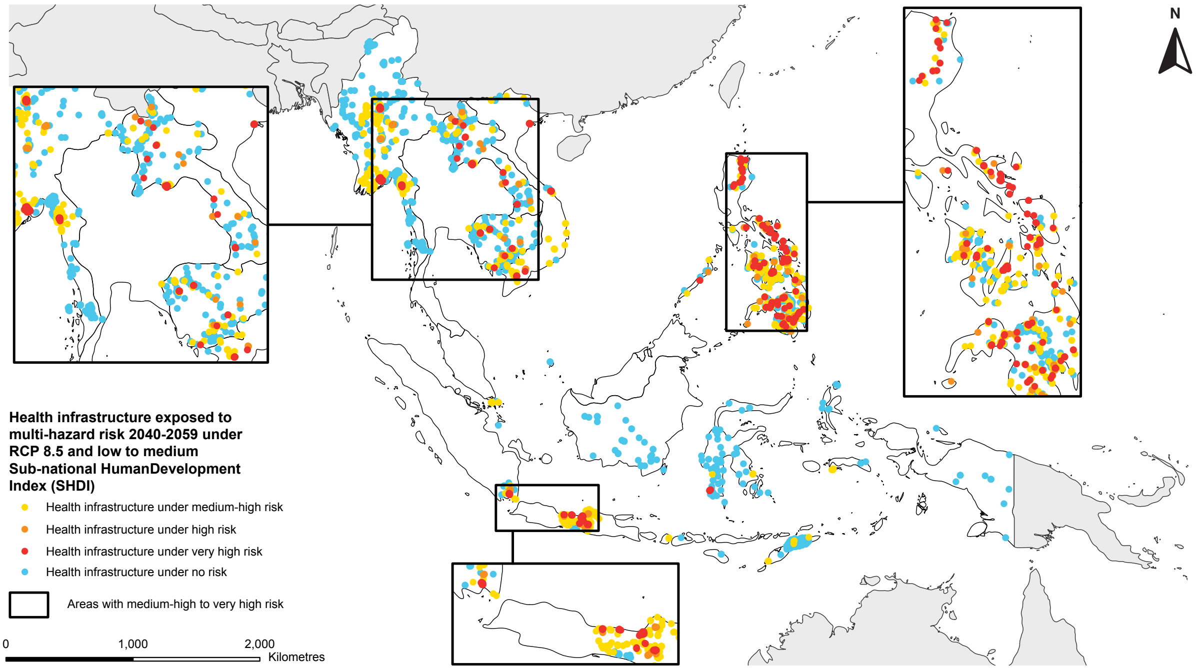
45 United Nations Office for the Coordination of Humanitarian Affairs (OHCA) Services, "Indonesia: Floods and Landslides – August 2021", 2021a. Available at https://reliefweb.int/disaster/fl-2021-000173-idn.

46 United Nations Country Team Viet Nam, "Viet Nam: Floods, Landslides and Storms – Office of the Resident Coordinator Flash Update No. 5 (As of 15 November 2020)", (15 November 2020). Available at https://reliefweb.int/report/viet-nam/viet-nam-floods-landslides-and-storms-office-resident-coordinator-flash-update-no-5.

Health-care infrastructure

Disasters can impose heavy pressures on health systems and disrupt health services, especially in areas with poor health conditions.[47] Figure 3-12 indicates the health-care facilities exposed to multi-hazard risk in low and medium HDI areas under the worst-case climate change scenario. The proportion of health-care facilities exposed to climate-related multi-hazards in the worst-case climate scenario (RCP 8.5, 2020–2059 average) is the highest in Viet Nam with 94 per cent. This is followed by Cambodia with 85 per cent, the Philippines with 79 per cent and Myanmar with 78 per cent of health facilities exposed to multi-hazard risks (Figure 3-13). To cope with cascading risks from natural and health hazards, health-care infrastructure should be risk-informed, and the resilience of health systems to changing climate conditions must be enhanced.[48]

FIGURE 3-12 **Health facilities in low to medium HDI exposed to multi-hazard risk under the worst-case climate change scenario (RCP 8.5)**



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; Disability-Adjusted Life Years (DALYs) estimates 2000-2019; UN WPP Adjusted Population Density 2020, v4.11; Sub-national Human Development Index (SHDI) version 4.0, 2018; and The Humanitarian Data Exchange (HDX) Version 1.51.0; and UN Geospatial.

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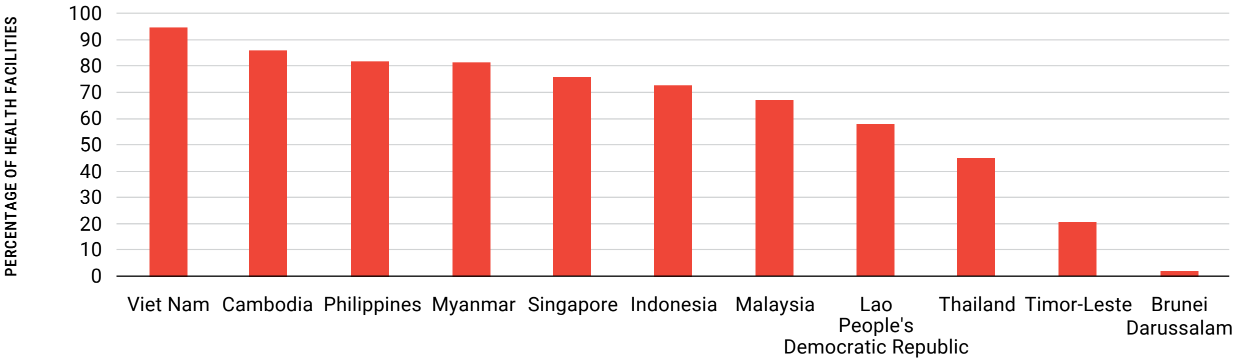
FIGURE 3-13 **Percentage of health facilities at risk of cascading multi-hazard risks under worst-case climate-change scenario (RCP 8.5, 2040–2059)**

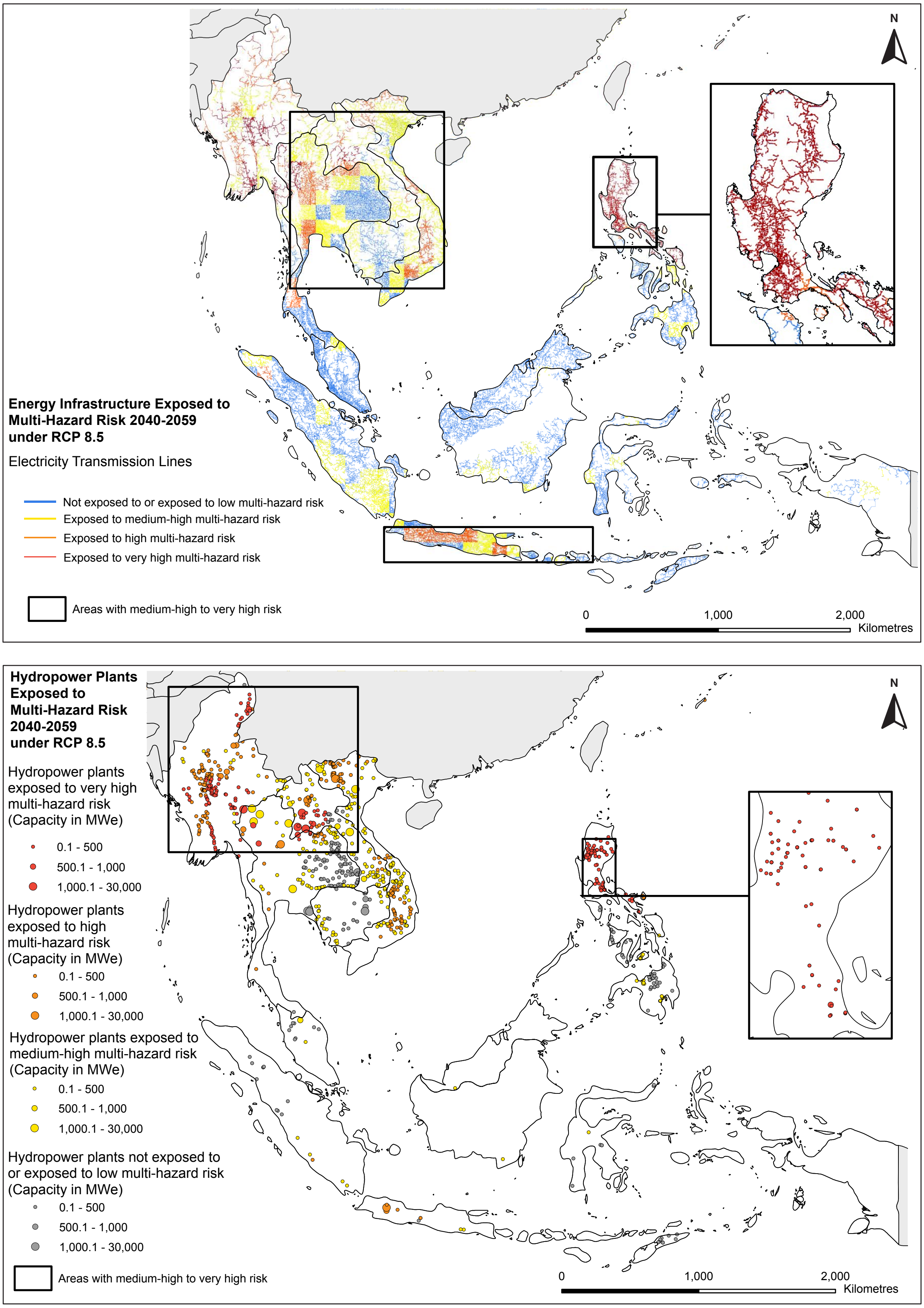


Source: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; World Bank, Climate Change Knowledge Portal, 2018; Disability-Adjusted Life Years (DALYs) estimates 2000–2019.

47 Sanaz Sohrabizadeh and others, "Systemic review of health sector responses to the coincidence of disasters and COVID-19", *BMC Public Health*, vol. 21, No. 709 (20 November 2021). Available at https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-10806-9.

48 "What impact will Cyclone Amphan have during COVID-19 times", *The Free Press Journal* (India), 19 May 2020. Available at https://www.freepressjournal.in/india/what-impact-will-cyclone-amphan-have-at-covid-19-times.

FIGURE 3-14 Electrical grid and hydropower plants exposed to multi-hazard risk under the worst-case scenario



Sources: ESCAP calculations, based on Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; Climate Change Knowledge Portal, 2018; Asia-Pacific Energy Portal, 2018; Global Electricity Transmission And Distribution Lines, 2020; and UN Geospatial.

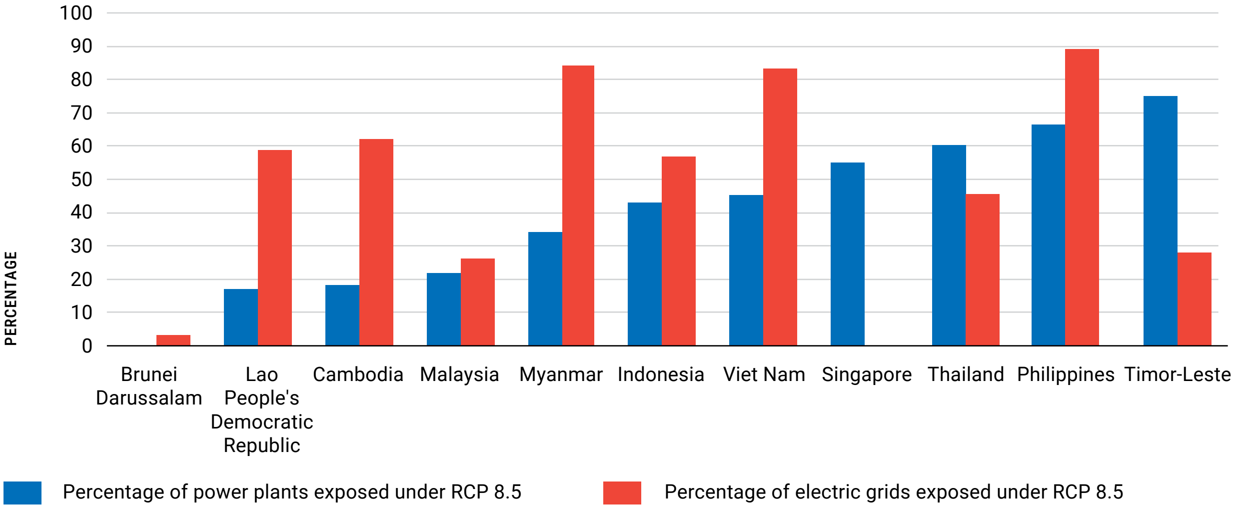
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Energy infrastructure

Natural hazards can damage energy infrastructure and disrupt the power supply when power plants and electricity transmission and distribution lines are present in hazard-prone areas. When the Philippines was hit by typhoons Conson and Chanthu, in September 2021, electricity and communication lines were disrupted in the affected provinces.[49] Extreme temperature and changes in precipitation can also affect the capacity of transmission lines, transformers and substations, and water volumes for hydropower plants.[50] Shutoffs and power outages can have significant repercussions on the economy and well-being of people.

In the region, electricity transmission and distribution lines, in Indonesia, the Philippines, Myanmar, Thailand, and Viet Nam, are highly exposed to multi-hazard risks (Figure 3-14). Many hydropower plants in these areas are also in multi-hazard risk areas (Figure 3-15), especially as the Lao People's Democratic Republic, Cambodia, Myanmar and Viet Nam are largely dependent on hydropower plants for their electricity generation. It is thus essential to make energy infrastructure, prone to multi-hazard risks, more resilient to ensure sustainable provision of electricity.

FIGURE 3-15 Percentage of the electrical grid and hydropower plants exposed to multi-hazard risk under the worst-case scenario, 2040–2059



Source: No source provided.

Out of the silos

The pandemic has been a stark reminder of the links and intersections between health and other natural hazards. Governments, however, often treat various types of emergencies separately, through different departments, each operating in their own 'silo' and with their specific Standard Operating Procedures (SOPs), which have resulted in gaps in preparedness.

The Sendai Framework for Disaster Risk Reduction 2015–2030 envisages, instead, a paradigm shift from managing disasters to managing risk. It calls for broadening the scope to consider both natural and anthropogenic hazards and the related environmental, technological and biological hazards and risks. In this regard, the following chapter discusses how South-East Asia can respond to the growing disaster-climate-health nexus.

49 United Nations Office for the Coordination of Humanitarian Affairs (OCHA), "Asia and the Pacific Weekly Regional Humanitarian Snapshot", 7–13 September 2021. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/ROAP_Snapshot_210913.pdf.

50 David Stoms, "Energy Infrastructure Risks from Climate Change", California Energy Commission, Energy Research and Development Division, 6 May 2014. Available at https://www.epa.gov/sites/production/files/2016-02/documents/stoms-infrastructure-risks-presentation-2014-wkshp.pdf (accessed on 26 February 2021).

CHAPTER 4

Building resilience to cascading risks to accelerate SDG implementation

Highlights

- The estimated cost of adapting to climate-related and biological hazards in South-East Asia is $24.9 billion under the worst-case climate change scenario, out of which $22.9 billion is the adaptation cost for climate-related hazards, and $1.9 billion for biological hazards.
- The economic recovery from the COVID-19 pandemic must include investing in climate adaptation to build resilient economies and populations to future crises and meet the targets of the Sustainable Development Goals.
- ESCAP's Risk and Resilience Portal shows that the top adaptation solutions for South-East Asia in order are:

  A Protecting mangroves;

  B Making water management systems more resilient;

  C Strengthening early warning systems (EWS);

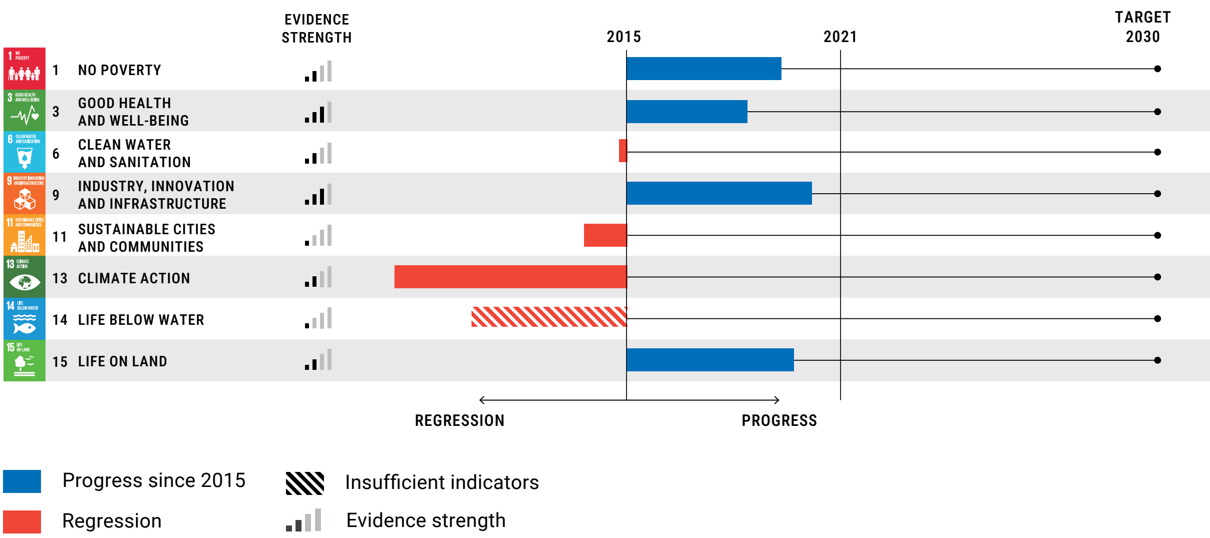
  D Improving dryland agriculture; and

  E Making new infrastructure resilient.

SDG progress and resilience of South-East Asia

Significant progress has been made towards achieving several of the Sustainable Development Goals in South-East Asia (Figure 4-1). Nevertheless, **gaps remain, especially as regression has been recorded for several goals, such as Goal 13 (Climate action), Goal 14 (Life below water) and Goal 16 (Peace, justice and strong institutions).** In particular, there is a reverse trend on Target 13.1 on resilience and adaptive capacity, and inadequate progress on Target 14.5 on conservation of coastal areas. These signal the need for enhanced adaptation measures to be put in place to build resilience and achieve the SDGs.

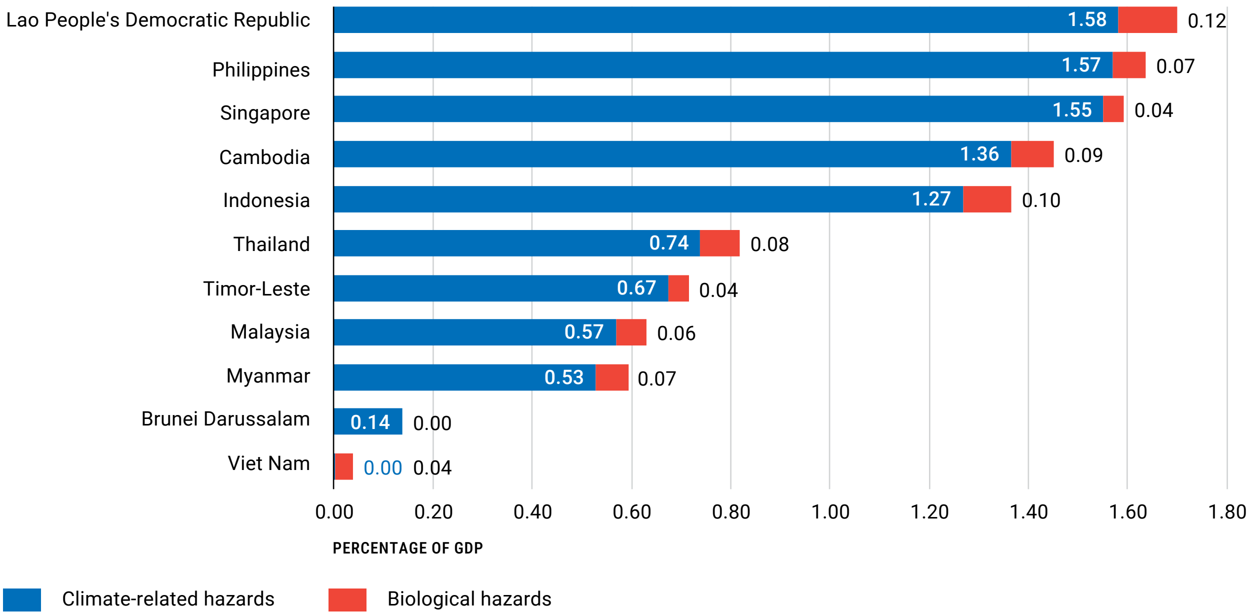
FIGURE 4-1 Snapshot of SDG progress in South-East Asia, 2021



Source: *Asia and the Pacific SDG Progress Report 2021* (United Nations publication, 2021).

ESCAP estimated a total annual adaptation cost of $24.9 billion for South-East Asia under the worst-case climate change scenario, from which $22.9 billion is the adaptation cost for climate-related hazards, and $1.9 billion is the adaptation cost for biological hazards. At the country level, the highest total adaptation cost is estimated for Indonesia at $8.5 billion, followed by the Philippines at $5.4 billion, and Thailand at $3.6 billion. However, when considering the size of the economy, the picture alters. Cambodia has the highest losses as a percentage of GDP, at 1.7 per cent, followed by the Lao People's Democratic Republic and the Philippines, both at 1.6 per cent of their GDP (Figure 4-2).

FIGURE 4-2 **Estimated adaptation cost to climate-related and biological hazards in South-East Asia, as a percentage of GDP**



Source: ESCAP, "Risk and Resilience Portal". Available at rrp.unescap.org.

Based on these adaptation cost estimates, Governments need to modify their nationally determined contributions (NDCs), and intended national determined contributions (INDCs). For instance, while the adaptation cost in the INDCs of Cambodia is marked at $200 million,[51] ESCAP calculations show that the adaptation cost should be raised to $400 million. Similarly, for the Lao People's Democratic Republic, while the INDC recorded $190 million as the adaptation commitment,[52] ESCAP calculations suggest that these should be increased to $270 million.

Building a more resilient South-East Asia through key adaptation measures

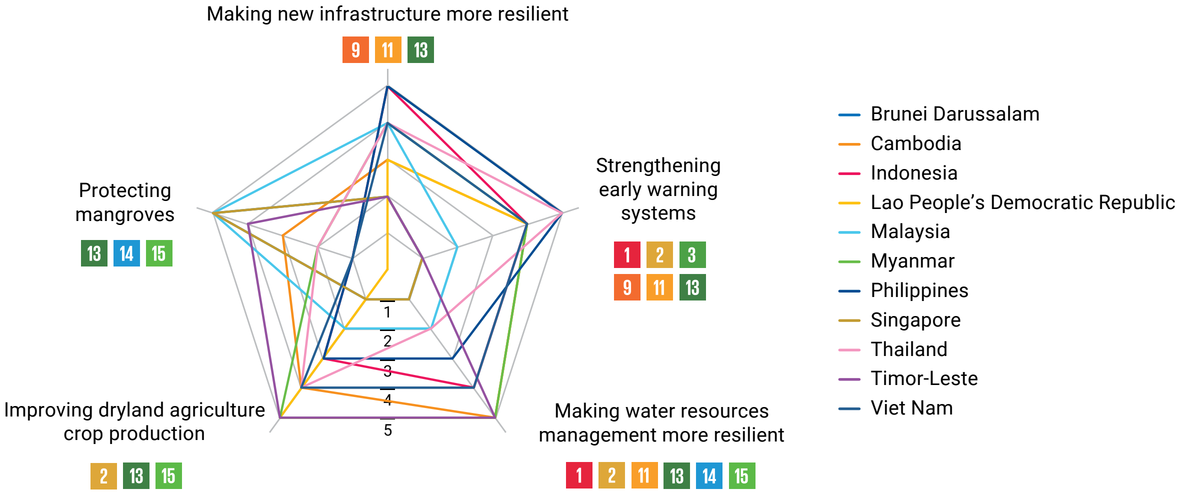
Countries need to invest in key adaptation priorities specific to their respective disaster riskscape. The Global Commission on Adaptation has established five key priorities that yield a high cost-benefit ratio for building resilience: strengthening early-warning systems; making new infrastructure resilient; making water resource management more resilient; improving dryland agriculture crop production; and protecting mangroves.[53]

Building on these 5 priorities, the following adaptation investment priority is specifically recommended for South-East Asia, in the order of their priorities together with their linkages to SDGs. The top adaptation priorities for South-East Asia are: protecting mangroves; making water resources management more

51 World Bank, "Nationally Determined Contributions (NDCs)", 2016. Available at http://spappssecext.worldbank.org/sites/indc/Pages/INDCHome.aspx.
52 Ibid.
53 Global Center on Adaptation, "Adapt now: A global call for leadership on climate resilience", 13 September 2019. Available at https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/.

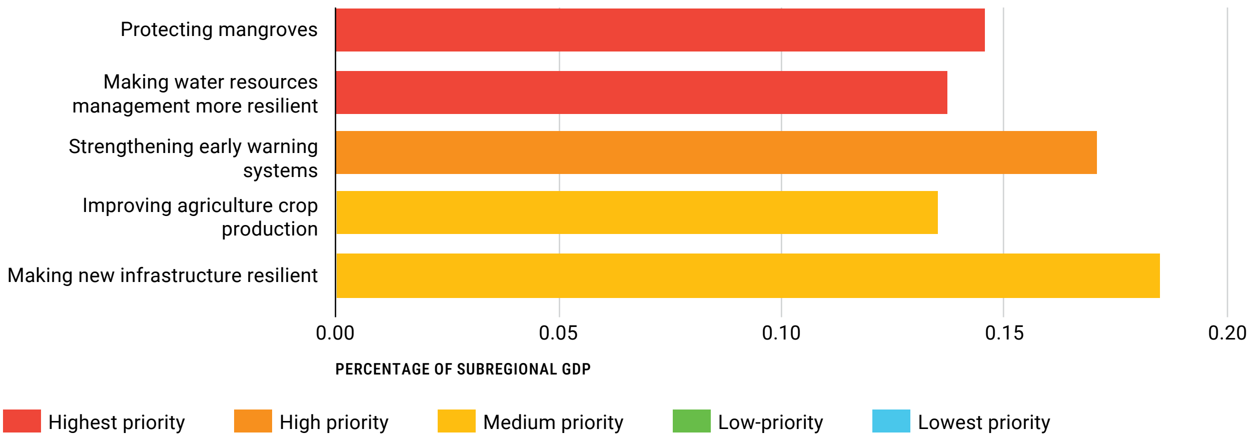
resilient; and strengthening early warning systems. Each country in South-East Asia also has their risk profile with a unique set of adaptation priorities. A country-level overview of South-East Asia can be seen in Figure 4-3. Figure 4-4 presents these priorities with the respective, estimated adaptation costs.

FIGURE 4-3 How the five priority adaption measures support achieving SDGs in South-East Asia



Source: ESCAP, based on Risk and Resilience Portal, "Adaptation Cost and Priorities for South-East Asia". Available at https://rrp.unescap.org/adaptation-and-priorities/sea.

FIGURE 4-4 Estimated adaptation cost and priorities for South-East Asia



Source: ESCAP, "Risk and Resilience Portal". Available at rrp.unescap.org.

Protecting mangroves

In South-East Asia, protecting mangroves is identified as the top priority for adaptation. One of the essential nature-based climate adaptation measures is the conservation and restoration of mangroves which face the threat of being converted for aquaculture and coastal development. Mangroves reduce the impact of typhoons, storm surges, coastal flooding and erosion (SDG 14: Life below water), and thus support climate adaptation (SDG 13: Climate action). A recent study coupling hydrodynamic and economic models has assessed the amount of property damage avoided each year due to mangrove cover.[54] Analysing the result with the average annual loss (AAL) due to typhoons, it is evident that disaster losses would increase substantially in the absence of the mangrove cover in South-East Asia, especially in Viet Nam, Indonesia and Thailand (Table 4-1).

54 Pelayo Menéndez and others, "The Global Flood Protection Benefits of Mangroves", *Scientific Reports*, vol. 10, No. 4404 (10 March 2020). Available at https://www.nature.com/articles/s41598-020-61136-6.

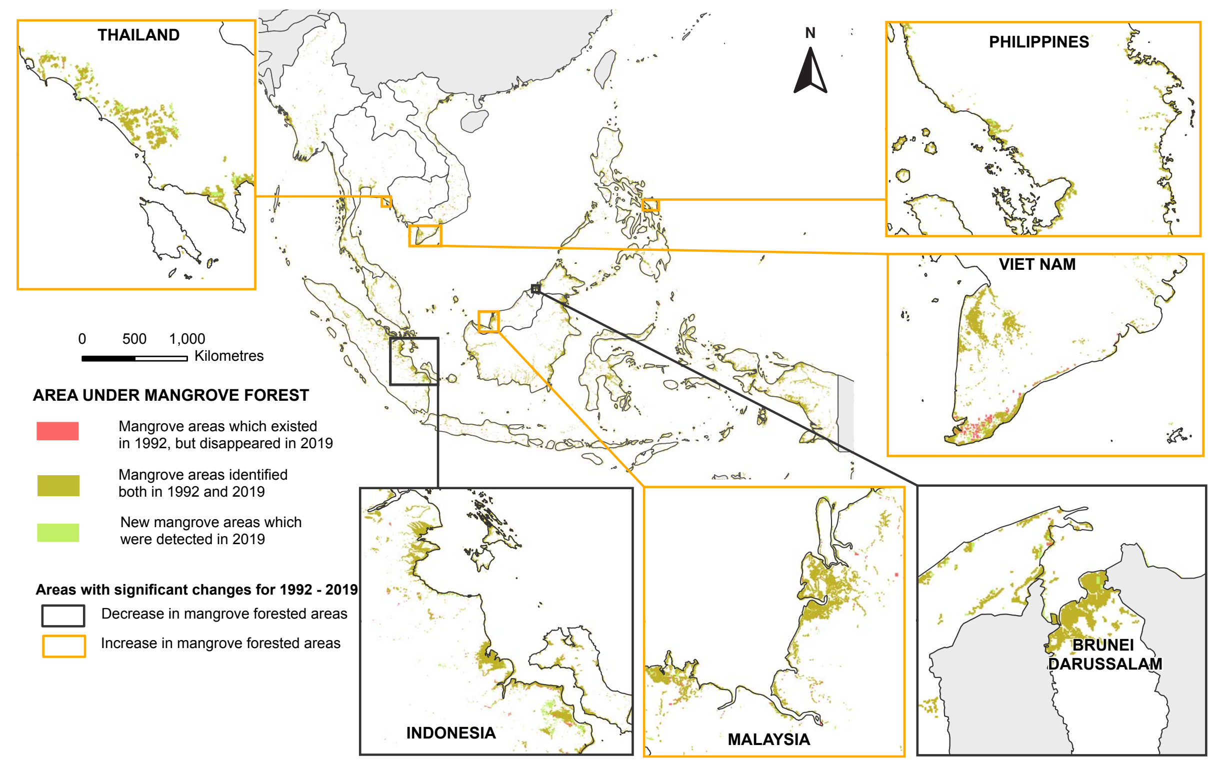
TABLE 4-1 Avoided losses due to mangrove cover and AAL from typhoons, $ billions

Country	Avoided property losses due to mangrove cover	Typhoon AAL – current scenario	Total losses if mangrove cover was lost
Brunei Darussalam	0.0060	0.0000	0.0060
Cambodia	0.0900	0.0000	0.0900
Malaysia	0.1410	0.0009	0.1419
Thailand	0.1470	0.0002	0.1472
Myanmar	0.1420	0.1499	0.2919
Indonesia	0.3200	0.0698	0.3898
Viet Nam	6.4450	0.1384	6.5834
Philippines	0.7580	12.0359	12.7939

Source: ESCAP calculations, based on Pelayo Menéndez and others, "The Global Flood Protection Benefits of Mangroves", Scientific Reports, vol. 10, No. 4404 (10 March 2020). Available at https://www.nature.com/articles/s41598-020-61136-6.
Note: Only countries from the above source are included. Countries highlighted in grey are those with higher avoided losses than current losses.

Mangroves in South-East Asia contribute to 58.5 per cent of mangroves areas in Asia and the Pacific.[55] Mangrove areas are widely spread across the region, including the coastal areas of Brunei Darussalam, Indonesia, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam.[56] Between 1992 and 2019, mangrove cover increased by 11.4 per cent in Thailand and Viet Nam, followed by 6.4 per cent in Myanmar and 3.7 per cent in Malaysia. However, in the same period, mangrove cover depleted by 1–2 per cent in Cambodia and Indonesia (Figures 4-5 and 4-6).

FIGURE 4-5 The area under mangrove cover, 1992 and 2019

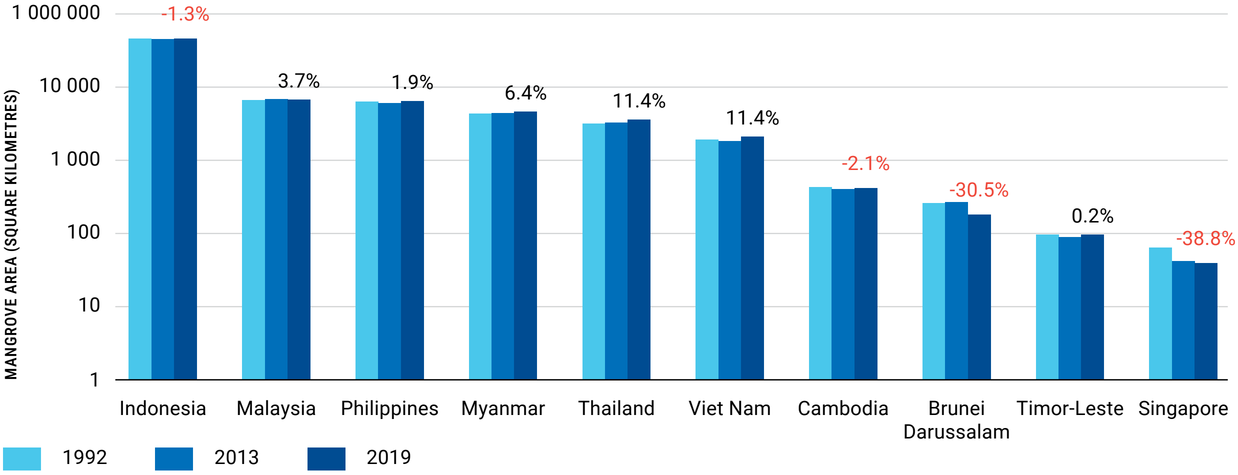


Source: ESCAP calculations based on Climate Change Initiative Land Cover, 2019 and UN Geospatial.
Note: All pixels under land cover class "Tree cover, flooded, saline water" was counted as coastal mangrove. The overall accuracy of the source data is 75.4%.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

55 Food and Agriculture Organization of the United Nations (FAO) and United Nations Environment Programme (UNEP) (1980). The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution. Available at https://www.fao.org/3/AB751E/AB751E01.htm.

56 Mai Sy Tuan, "Mangrove-related policy and institutional framework in Vietnam", Final Workshop for 'Income for Coastal Communities for Mangrove Protection' Project, Food and Agriculture Organization of the United Nations (FAO), 2016. Available at https://www.fao.org/fileadmin/templates/rap/files/meetings/2016/161220_05_Vietnam_policy_presentation.pdf.

FIGURE 4-6 Area of mangrove forest and percentage change, by country, 1992–2019



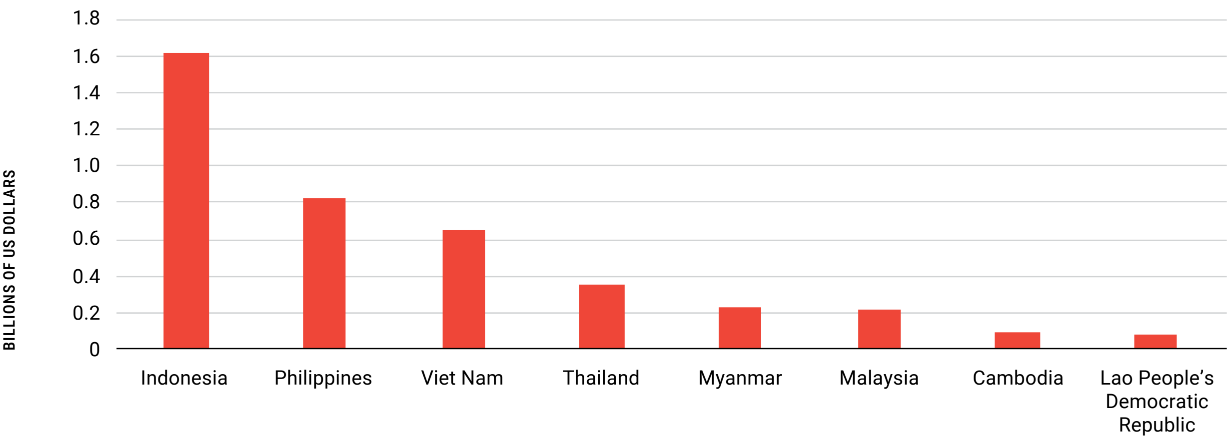
Source: ESCAP calculations based on Climate Change Initiative Land Cover, 2019.
Note: The Y-axis scale is logarithmic.

Making water resources management more resilient

As countries greatly suffer from water-related natural hazards, establishing resilience in water resources management is proposed as one of the top adaptation priorities for South-East Asia. It will help address water-related disasters (SDG 2: Zero hunger, SDG 14: Life below water, and SDG 15: Life on land), protect the most vulnerable (SDG 1: No poverty, SDG 11: Sustainable cities and communities), and help adapt to climate change (SDG 13: Climate action).

Sustainable year-round solutions for water resource management include rainwater harvesting and wastewater reuse. It will also be essential to strengthen traditional water management systems. It is estimated that around 0.14 per cent of subregional GDP is required for making water resources management more resilient in South-East Asia.[57] Furthermore, it is estimated that Indonesia will need to invest more than $1.6 billion for such adaptation. Adaptation costs for resilient water resources management for the Philippines and Viet Nam are estimated to be around $820 million and $650 million, respectively (Figure 4-7).

FIGURE 4-7 Estimated adaptation cost for making water resources management more resilient in South-East Asian countries



Data source: ESCAP, "Risk and Resilience Portal". Available at rrp.unescap.org.

57 United Nations Economic and Social Commission for Asia and the Pacific, "Risk and Resilience Portal". Available at https://rrp.unescap.org.

BOX 4-1 Transboundary cooperation for water resources management in the Mekong-Lancang River basin

The Mekong-Lancang River basin is at risk of climate change-induced disasters, particularly to extreme floods and droughts, resulting in water scarcity and a decline in agricultural production, among others. Noting that water resources management holds immense potential to build the resilience of the communities in the basin, the Mekong Institute and the Ministry of Natural Resources and Environment of Thailand implemented a joint project on Transboundary Cooperation Mechanism on Adaptation and Climate Change and Hydropower Development Projects from 2018–2019.

The project successfully fostered an open forum for collaboration and cooperation on transboundary water resources in the Mekong-Lancang region. The regional country representatives came together to discuss policy interests in furthering the role of hydropower and large water storage projects to contribute to climate adaptation. The objectives were driven by direct engagement with national experts from China, the Lao People's Democratic Republic and Thailand as part of the technical support team and key agencies in six countries in the region.

The key action areas included establishing a cooperation mechanism on water level, flow fluctuations and reservoir management; increasing community awareness of climate change impacts, mitigation and adaptation measures; and broadening the understanding of such hydropower development projects and their operations.

Source: Mekong Institute, "Transboundary Water Cooperation: Promoting Climate Change Resilience in Mekong River Basin Communities", 2022. Available at https://www.mekonginstitute.org/what-we-do/ongoing-projects/transboundary-water-cooperation/; and Mekong Institute – Agricultural Development and Commercialization Department, "Transboundary Cooperation Mechanism on Adaptation to Climate Change and Hydropower Development Project", Lancang-Mekong Cooperation Special Fund Project Completion Report, 6 December 2019. Available at http://fad.onwr.go.th/file/mlc/01_Final%20Project%20Report_6Dec2019_ONWR.pdf.

BOX 4-2 The success of community-level water resources management in Chiang Mai, Thailand

The Hua Sai Community of nearly 2,000 people live in Chiang Mai province, Thailand. Hua Sai, a small river provides water for the communities here. Over the years, poor water resources management and increased agricultural demand for water resources have led to severe water scarcity.

Subsequently, the Hua Sai Reservoir Community was established to tackle the challenges and ensure proper water distribution with **Community Water Resources Management (CWRM)**. The work entailed the following:

- Training on how to analyse water balance and identify suitable locations for water pipelines for improved distribution;
- Development of mechanisms for landowners to pay for the cost, and learn to place the water pipelines themselves;
- Restoration of upstream forest and development of a conservation map to set boundaries between preserved land and arable areas;
- Development of community-level regulations for the management of water resources and the forest; and
- Shifting from monocrop to integrated agriculture and sharing knowledge within the established community groups for rice farming, mushroom growing, and organic vegetables.

As a result, from a single water dispenser line that supplied water to 0.64 km^2 of agricultural area in 1998, the Huai Sai Reservoir Community installed 20 lines, distributing water to 224 households and to 3.43 km^2 of agricultural land. This change has also contributed to the significant increase of household income and building the community resilience to drought risks.

Source: Utokapat Foundation Under the Royal Patronage of H.M the King, "Application of Science and Technology for Community Water-Related Disaster Risk Reduction: Thailand Good Practices following His Majesty the King's Initiative towards Sustainable Development", 2016. Available at https://www.preventionweb.net/files/51880_wrdrrbook1.pdf.

Strengthening early warning systems

As recognized in target G of the Sendai Framework for Disaster Risk Reduction 2015–2030, disaster risk reduction and climate change adaptation will require sound multi-hazard early warning systems. Strengthening early warning systems will support better protection and services to the vulnerable (SDG 1: No poverty, SDG 3: Good health and well-being). It will also allow farmers, agricultural ministries, and other stakeholders to take early actions (SDG 2: Zero hunger) and help disaster management authorities identify critical infrastructure exposed to potential hazards (SDG 9: Industry, innovation and infrastructure, SDG 11: Sustainable cities and communities), and prepare for extreme weather events (SDG 13: Climate action).

Early warning systems are already identified as a top priority in the NDCs on climate change of many least developed countries (LDCs). Yet, countries often lack the capacity or financial resources to develop sound end-to-end multi-hazard early warning systems. ESCAP, in partnership with the World Meteorological Organization (WMO) and other organizations, has worked on strengthening early warning systems in high-risk countries, taking advantage of the regional and subregional climate outlook forums and global and regional initiatives, such as Climate Risk & Early Warning Systems (CREWS). The ESCAP/WMO Typhoon Committee and the WMO/ESCAP Panel on Tropical Cyclones have provided technical support and cooperation across the region for several decades. The ESCAP Multi-Donor Trust Fund for Tsunami, Disaster and Climate Preparedness in the Indian Ocean and Southeast Asian Countries has provided financial support for key initiatives that deliver cost-effective, early warning products and services. These initiatives and programs, backed by member States, have effectively supported work on strengthening early warning systems in the region.

Improving dryland agriculture

Agriculture continues to be one of the sectors most impacted by extreme weather events.[58] For instance, in Timor-Leste, flash floods resulting from heavy rains, from 29 March to 4 April 2021, affected more than 1,200 hectares of agricultural area in the Manatuto district. The flash floods hit the country where agriculture constitutes 70 per cent of the population's main source of livelihood ahead of the harvest season.[59] **This highlights the importance of building resilience in the agriculture sector** through integrated soil fertility management and watershed management to reduce soil erosion and runoff, vegetation management, and sustainable forest management. This will contribute to the achievement of SDG 2: Zero hunger, SDG 13: Climate action, and SDG 15: Life on land, among others.

Focussed on the specific risk landscape and policy gaps in South-East Asia, the ASEAN Regional Plan of Action for Adaptation to Drought (ARPA-AD) **recommends a way forward to enhance coordination at the regional, national, and international levels for achieving sustainable management of drought.** The study considers the impact of drought on the livelihood of people, natural resources and ecosystem, agriculture, energy and sustainable socioeconomic development. It focuses on action and cooperation on three parallel tracks of drought intervention: 'reduce and prevent', 'prepare and respond' and 'restore and recover'.[60] Putting these into practice would enhance the resilience of dryland agriculture systems and the related socioeconomic drivers.

58 World Meteorological Organization, "State of the Climate Report in South-West Pacific 2020", WMO-No. 1276, 2021. Available at https://library.wmo.int/doc_num.php?explnum_id=10900.

59 United Nations Country Team Timor-Leste, "Joint Appeal and Food Response Plan Towards Recovery – Timor-Leste", May 2021. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/2021%20TL%20Flood%20Response%20Plan%20FINAL%20210528%20%28rev%29.pdf.

60 ASEAN Secretariat and ESCAP, "ASEAN Regional Plan of Action for Adaptation to Drought 2021–2025" (Jakarta, The ASEAN Secretariat, 2021). Available at https://asean.org/wp-content/uploads/2021/11/ASEAN-Regional-Plan-of-Action_011121-FINAL-EDIT.pdf.

BOX 4-3 ASEAN Regional Plan of Action for Adaptation to Drought

The ASEAN Regional Plan of Action for Adaptation to Drought aims to develop policies for managing drought risk, strengthening adaptive capacity, and minimising the drought vulnerability of impacted groups and sectors. It considers a wide range of factors, such as the region's historical and current drought situation and challenges, and proposes three parallel tracks for drought adaptation.

FIGURE A Three parallel tracks for drought adaptation

TRACK 1 REDUCE/PREVENT	TRACK 2 PREPARE/RESPOND	TRACK 3 RESTORE/RECOVER
Managing food (agriculture), water and energy	Risk assessment, monitoring and early warning	Risk financing and insurance
Climate-resilient water infrastructure	Climate services, data and innovations	Forecast-based financing
		Social safety nets

Source: *Ready for the Dry Years: Building resilience to drought in South-East Asia with a focus on Cambodia, Lao People's Democratic Republic, Myanmar and Viet Nam: 2020 Update* (United Nations publication, 2020b). Available at https://www.unescap.org/sites/default/files/publications/Ready%20for%20the%20Dry%20Years.pdf.

Referring to the three parallel tracks, the Regional Plan consists of nine action groups:

1 risk, impact and vulnerability assessment,

2 early warning, preparedness and planning,

3 adaptation actions,

4 response and recovery,

5 strengthening coordination between ASEAN sectoral bodies,

6 partnership and collaboration,

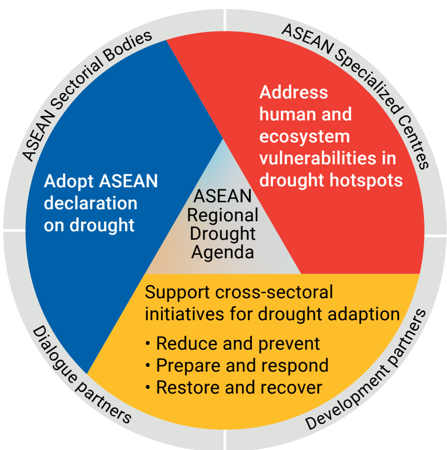
7 capacity-building/enhancement,

8 data-sharing and dissemination, and

9 monitoring and evaluation.

Following the preparation and the planning phase, the implementation phase will involve all key personnel, sectoral bodies, stakeholders and partners.

FIGURE B Proposed implementation arrangement

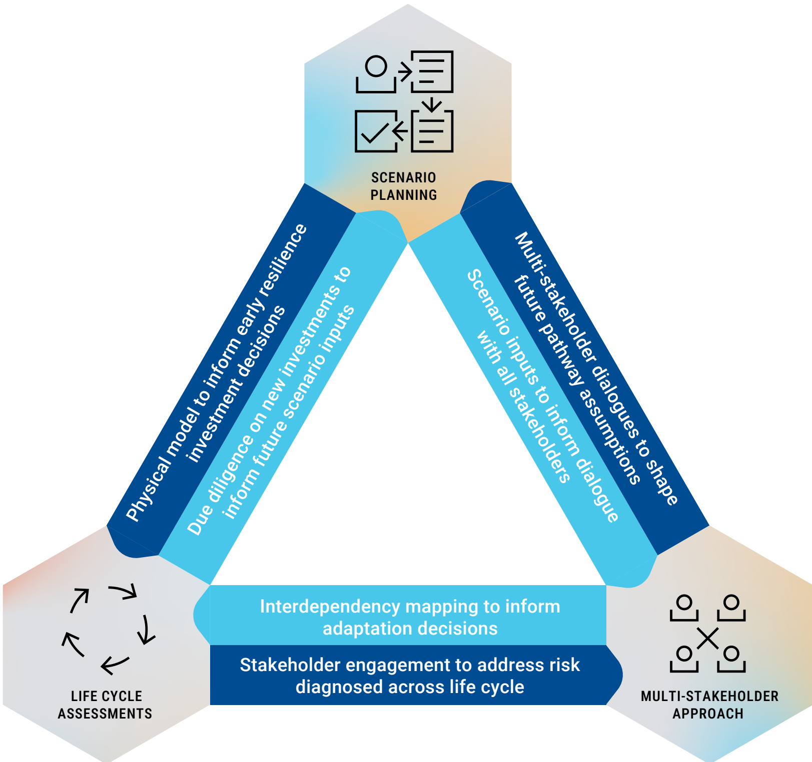


Source: ASEAN Secretariat and ESCAP, "ASEAN Regional Plan of Action for Adaptation to Drought 2021-2025" (Jakarta, The ASEAN Secretariat, 2021). Available at https://www.unescap.org/kp/2021/asean-regional-plan-action-adaptation-drought-2021-2025.

Making new infrastructure resilient

All infrastructure investments should be risk-informed. Infrastructure covers discrete assets, such as roads and buildings, and collective sets of systems and services, that can be synchronized to provide essential services. In this regard, it is recommended to take a three-pillar approach: dynamic scenario planning, lifecycle assessments and multi-stakeholder engagement, with multiple interdependencies among the three pillars (Figure 4-8).[61]

FIGURE 4-8 **A three-pillar approach for risk-informed infrastructure**



Source: Adapted from Marsh & McLennan Advantage, "Global Risks for Infrastructure: The climate challenge", 2020. Available at https://www.mmc.com/content/dam/mmc-web/insights/publications/2020/august/Global-Risks-for-Infrastructure_The-Climate-Challenge_Final.pdf.

Dynamic scenario planning should combine all technical innovations, analytics and expertise to understand the sensitivity and exposure of infrastructure and related services in the face of climate hazards. For example, all new infrastructure should consider rising sea levels and potentially increasing storms in coastal cities. Effective climate risk integration should engage all stakeholders in short- medium- and long-term scenario planning and lifecycle infrastructure assessments.

In addition to these three pillars, all new infrastructure and retrofits to existing infrastructure must consider changing natural ecosystems. The best way to do this is by combining traditional grey infrastructure with green infrastructure. For example, for water resource management, grey infrastructure components would include building reservoirs, pipe networks and treatment plants, while complimentary green infrastructure would include watersheds that improve source water quality and wetlands to filter wastewater effluents. This is not only a cost-effective approach, but it also empowers communities by engaging local stakeholders and incorporates longer-term flexibility for responding to changing climate.[62] Building infrastructure resilience would support the achievement of SDG 9: Industry, innovation and infrastructure, SDG 11: Sustainable cities and communities, and SDG 13: Climate action (Box 4-4).

61 Marsh & McLennan Advantage, "Global Risks for Infrastructure: The climate challenge", 2020. Available at https://www.mmc.com/content/dam/mmc-web/insights/publications/2020/august/Global-Risks-for-Infrastructure_The-Climate-Challenge_Final.pdf.

62 Greg Browder and others, *Integrating Green and Gray Creating Next Generation Infrastructure* (Washington D.C., World Bank and World Resources Institute, 2019). Available at https://openknowledge.worldbank.org/handle/10986/31430.

BOX 4-4 AADMER 2021–2025: Shifting from emergency response to building resilience

ASEAN countries have historically experienced a host of disasters ranging from earthquakes, floods, landslides, and typhoons. The wide geographic stretch of incidences and increasing frequency of disasters require ASEAN communities to enhance their readiness and emergency response capacity. The ASEAN Agreement on Disaster Management and Emergency Response (AADMER) ratified in 2009 has driven the operationalization of disaster response in ASEAN. The New Work Programme 2021-2025 particularly moves beyond response to address concerns of vulnerability to natural disasters which are increasing in intensity and frequency, to put forth climate change adaptation initiatives, and to guide the regional cooperation in the field of disaster management and response.

Noting the importance of the global agreements in providing adaptation and mitigation guidance for climate change, the new plan aligns with relevant global agreements, including the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR); the Paris Agreement on Climate Change and 2030 Agenda on Sustainable Development. By aligning with the SFDRR and the relevant SDGs, the AADMER Work Programme 2021-2025 will implement both the relevant provisions of the AADMER and the relevant global targets and goals that are scalable and regionally applicable.

The five priority programmes comprehensively address the issues of climate change and adaption to climate change through:

1. Risk Assessment and Monitoring (RAM)
2. Prevention and Mitigation (P&M)
3. Preparedness and Response (P&R)
4. Resilient Recovery (RR)
5. Global Leadership (GL)

Source : https://asean.org/wp-content/uploads/2021/08/AADMER-Work-Programme-2021-2025.pdf.

CHAPTER 5

Transformative actions to build resilience

Highlights

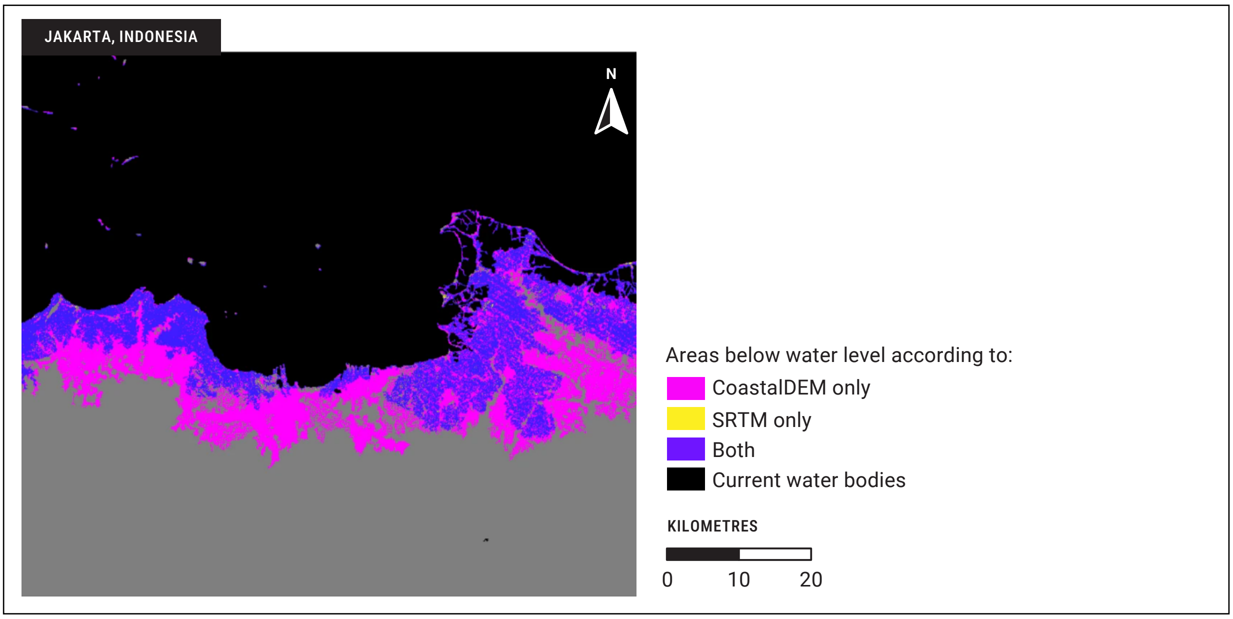
- Frontier technologies and digital solutions not only enable authorities to combat a pandemic but also enhance service provision to citizens through, for example, digital payment ecosystems and shock-responsive cash transfer systems.
- It is recommended that risk analytics are incorporated into policymaking processes and to operationalize impact-based forecasting to support risk-informed decision-making and early action.
- Innovation ecosystems with strategic foresight driven by technology are crucial for building back better from the pandemic.

Frontier technology and digital solutions

For managing the COVID-19 pandemic, countries in South-East Asia have been able to take advantage of 'frontier technologies' used in disaster risk reduction and in the health sector. These include artificial intelligence (AI), big data, machine learning, 5G technologies, drones, automated vehicles, and robotics.

These technologies are critical drivers of disaster risk reduction, including developing a resilient health sector and addressing some of the existing gaps in managing systemic risks. Technological innovations could expand the connectivity of people, things and information, for instance, in cloud computing, 5G Mobile Technology, wireless mesh networks, mobile messaging, the Internet of Things, and blockchain. Presentation through augmented and virtual reality can also be improved. For instance, AI and machine-learning applications have already substantially reduced uncertainties in the forecasts of coastal inundations due to sea-level rise. Coastal Digital Elevation Models (Coastal DEM) elevation data indicate that by 2100, land, currently home to many people, could fall permanently below the high-tide line (Figure 5-1).[63]

FIGURE 5-1 **Permanent inundation surfaces in Indonesia predicted by Coastal DEM and Shuttle Radar Topography Mission (SRTM) digital elevation model (RCP 8.5, 2100)**



Source: Scott A. Kulp and Benjamin H. Strauss, "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding", *Nature Communications*, vol. 10, No. 4844 (2019). Available at https://www.nature.com/articles/s41467-019-12808-z.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

63 Scott A. Kulp and Benjamin H. Strauss, "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding", *Nature Communications*, vol. 10, No. 4844 (2019). Available at https://www.nature.com/articles/s41467-019-12808-z.

Academic courses and training on technology and satellite data-driven disaster risk reduction solutions and climate adaptation are also increasing, which contribute toward building the expertise of young professionals in this area. For instance, led by the Government, the Philippine Space Agency's (PhilSA) Advanced Degrees for Accelerating Strategic Space R&D and Applications (AD ASTRA) scholarship programme provides students with financial assistance to pursue further education in the fields related to space science, technology and applications, especially in areas, such as atmospheric sciences, hydrological science, climate change, among others.[64] The Geo-Information and Space Technology Development Agency (GISTDA) in Thailand, and the ASEAN Research and Training Center for Space Technology and Application (ARTSA) also promote better understanding and monitoring of droughts and carry out capacity-building activities on Earth observation (EO) and geo-information technology (GI) especially for women researchers.[65] The ASEAN Disaster Resilience Outlook also highlights measures to address the digital divide in ASEAN by 2030 through increasing penetration of existing Internet connections and utilizing satellite solutions, building digital literacy and social media outreach. These can be effective to better prepare for a disaster or emergency as well as to build resilience.[66]

Digital solutions can also be used to support social protection during a disaster. Countries with well-developed digital payments ecosystems, and shock-responsive social cash transfer systems, have been able to respond rapidly to help poor and vulnerable communities when disasters hit. During a pandemic, digital transfers offer a further advantage of reducing physical contact when people collect their payments. Indonesia introduced technology to verify citizen identities to disburse social assistance subsidies.[67] The Philippines and Thailand are also progressing towards infrastructural and regulatory foundations for digital IDs.[68] For example, Thailand was able to implement government-to-person (G2P) rapid disbursements while observing social distancing via national IDs that were linked to bank accounts. Singapore has also released its national digital identity platform, SingPass. It allows access to 1,700 government and private sector services online and in person. It is operated by the Government Technology Agency (GovTech), and recognized as one of their eight strategic national projects in Singapore's Smart Nation vision.[69]

Table 5-1 presents some latest technologies for DRR and the health sector in South-East Asia.

Risk analytics

During extreme events – whether meteorological, climatic or biological – risk analytics can now use multiple data platforms and models for gathering information from sensor webs, the Internet of Things, and social media.[70] This can generate a greater variety and volume of data at high velocity that can be fed into a cloud-based high-speed computational infrastructure to provide real-time solutions.

For instance, the decision support system of ESCAP's Risk and Resilience Portal provides a contextual analysis of risk based on INFORM Sub-National Risk Index to support informed decision-making of selected countries (Figure 5-2).

64 Republic of the Philippines, Philippine Space Agency (PhilSA), "Advanced Degrees for Accelerating Strategic Space R&D and Applications (PhilSA AD ASTRA) Scholarships", 26 November 2021. Available at https://philsa.gov.ph/news/philsa-advanced-degrees-for-accelerating-strategic-space-rd-and-applications-philsa-ad-astra-scholarships/.

65 GISTDA, "Drought Monitoring". Available at http://artsa.gistda.or.th/clmt/.

66 ASEAN Secretariat, "ASEAN Disaster Resilience Outlook: Preparing for a future and beyond" (Jakarta, The ASEAN Secretariat, 2021a). Available at https://asean.org/book/asean-disaster-resilience-outlook-preparing-for-a-future-beyond-2025/.

67 Eisya A. Eloksari, "Government trials facial recognition system to improve social aid disbursement", *The Jakarta Post*, 22 May 2020. Available at https://www.thejakartapost.com/news/2020/05/22/government-trials-facial-recognition-system-to-improve-social-aid-disbursement.html.

68 Luana Pascu, "Philippines biometric national ID system pre-registration to start in Q4, prioritize the unbanked", Biometric Update.com, 3 September 2020. Available at https://www.biometricupdate.com/202009/philippines-biometric-national-id-system-pre-registration-to-start-in-q4-prioritize-the-unbanked.

69 Govtech Singapore, "Singpass". Available at https://www.tech.gov.sg/products-and-services/singpass/?utm_source=products_homepage (accessed on 19 December 2021).

70 Alexander Y. Sun and Bridget R. Scanlon, "How can Big Data and machine learning benefit environment and water management: A survey of methods, applications, and future directions", *Environmental Research Letters,* vol. 14, No. 7 (1 July 2019). Available at https://iopscience.iop.org/article/10.1088/1748-9326/ab1b7d.

TABLE 5-1 **Frontier technologies for DRR and health sector in South-East Asia**

Technology	Disaster risk reduction	Health sector
Big data	**Philippines** – *Crowdsourced disaster information sharing* During several typhoons in 2020, a web-based app was used by residents and by disaster management agencies to identify areas in need of immediate response and for rescue efforts.[71,72]	**Malaysia** – *MySejahtera – COVID-19 tracking* MySejahtera is an application that allows the Government to conduct complex research using big data-based analytical techniques. It monitors virus spread, detects trends in the COVID-19 outbreak, and helps users to assess their health risk and locate hospitals and clinics.[73,74]
Robotics	**Philippines** – *Drones for post-disaster operations* In 2020, an earthquake of magnitude 6.1 shook the Philippines island of Luzon, and an earthquake of magnitude 6.4 struck the Visayas islands. Unmanned Aerial Vehicles (UAVs) were used to monitor road conditions, assist rescuers in locating stranded persons, and act as alternative modes of transport for various payloads.[75]	
Artificial Intelligence (AI)	**Viet Nam** – *Drought forecasting and planning* A geospatial tool provides data for daily drought indicators and a three-month forecast. It is currently being extended to include rice output estimation. This publicly accessible tool will enable a diverse range of users, from hydro-meteorologists to agricultural planners.[76] **Thailand** – *Flash flood forecasting and early warning system* This system forecasts flash flood areas hourly and daily using rainfall forecasting and soil moisture data. The high-risk region is assessed using a flash flood potential index, updated with satellites and radar data to measure five-day accumulated rainfall. Finally, a 24-hour risk forecast is produced, followed by warnings of flash floods in sub-districts.[77]	**Viet Nam** - *Tracking hospital capacity* A smart medical operating centre using AI was launched in Ho Chi Minh city in Feb 2020. The pilot project updates information at 47 city hospitals, tracking their capacity to receive and treat patients.[78] **Indonesia** – *Early detection of cataract* Indonesian start-up CekMata uses AI and machine learning for the early detection of cataracts. Users upload a close-up of their eyes, and the system detects any sign of infection. If it finds an anomaly, the system directs the user to the nearest ophthalmologist or hospital.[79]
Internet of Things		**Singapore** – *Spyder ECG – Wireless ECG monitoring system* Spyder ECG is a wireless ECG monitoring system developed by the WEB Digital Heart Health Company in Singapore. Spyder ECG uses cloud-based technologies to collect continuous live-streamed ECGs from any location and allows real-time assessment and review by a physician from a remote location.[80,81]
Satellite data	**Myanmar** – *Improving understanding of flood risk through satellite data* A systematic decision-support tool has been developed based on flood hazard and exposure indices. This will enable the identification of high-risk areas based on historical flood frequency while also incorporating socioeconomic and population data. This tool can improve the pre-allocation of flood relief supplies to the high flood risk townships and identify possible shelter sites.[82]	**Indonesia** – *GIS-based approaches for accessibility of referral hospital during COVID-19* In Jakarta, which recorded the highest COVID-19 cases in the country, the spatial pattern of case distribution was calculated using verifiable data from the local government. A service area and origin-destination cost matrix were created to assist an existing referral hospital and develop a standard deviation ellipse model to assess the spatial distribution of COVID-19.[83]

71 Petabencana, "As consecutive typhoons strike the Philippines, community-led data sharing assists in relief efforts", 20 November 2020. Available at https://info.petabencana.id/2020/11/20/as-consecutive-typhoons-strike-the-philippines-community-led-data-sharing-assists-in-relief-efforts/.

72 Yayasan Peta Bencana, "MapaKalamidad", 2020. Available at https://mapakalamidad.ph/.

73 Mohit Sagar, "Malaysia Government next to launch app to monitor COVID-19 outbreak", OpenGov, 7 April 2020. Available at https://opengovasia.com/malaysia-government-next-to-launch-app-to-monitor-covid-19-outbreak/.

74 Government of Malaysia, "MySejahtera", (2021a). Available at https://mysejahtera.malaysia.gov.my/intro_en/.

75 Nicoletta Metri, "Testing Drones for Post-Disaster Operations in the Philippines", Internet Society Foundation, 14 May 2019. Available at https://www.isocfoundation.org/story/testing-drones-for-post-disaster-operations-in-the-philippines/.

76 United Nations Office for Disaster Risk Reduction, "Status of Science and Technology in Disaster Risk Reduction in Asia-Pacific", 2020b. Available at https://www.undrr.org/publication/status-science-and-technology-disaster-risk-reduction-asia-pacific-2020.

77 Ibid.

78 mClinica pharmacy solutions, "AI Adoption in Southeast Asia's Healthcare Systems: Innovative health technologies improve patient care and deliver cost savings", 1 October 2020. Available at https://www.mclinica.com/ai-adoption-in-southeast-asias-healthcare-systems/.

79 Ibid.

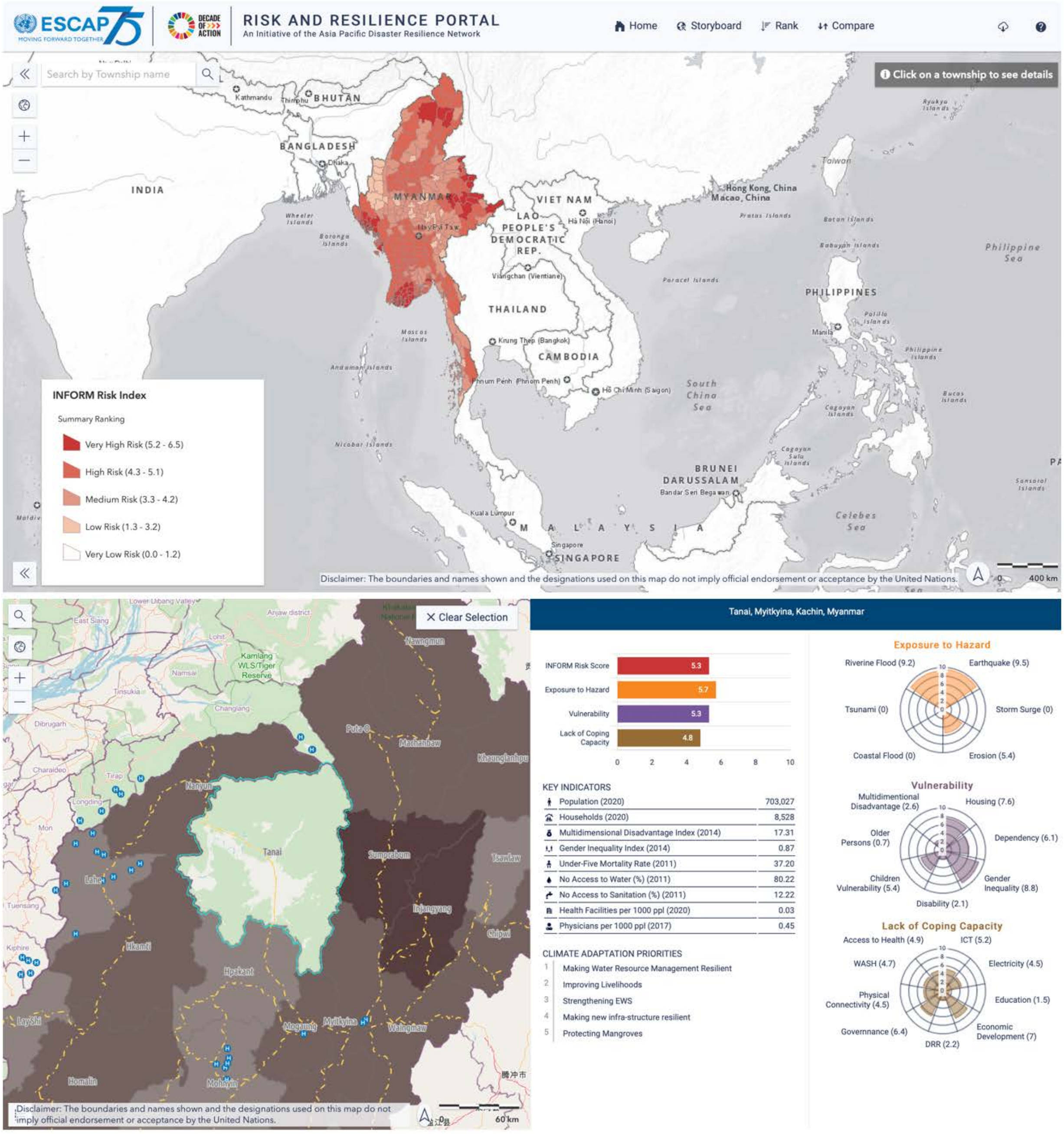
80 Spyder Wireless ECG Monitoring System, "SPYDER ECG Solution", 2020. Available at https://www.spyderecg.com/.

81 Rajashekhar Karjaji, and Manish Jindal Manish, "What can IoT do for healthcare?" Wipro, 2020. Available at https://www.wipro.com/business-process/what-can-iot-do-for-healthcare-/.

82 United Nations Office for Disaster Risk Reduction, "Status of Science and Technology in Disaster Risk Reduction in Asia-Pacific", 2020b. Available at https://www.undrr.org/publication/status-science-and-technology-disaster-risk-reduction-asia-pacific-2020.

83 Florence E. S. Silalahi, and others, "GIS-based approaches on the accessibility of referral hospital using network analysis and the spatial distribution model of the spreading case of COVID-19 in Jakarta, Indonesia", *BMC Health Services Research*, vol. 20, No. 1053 (20 November 2020). Available at https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-020-05896-x.

FIGURE 5-2 ESCAP Risk and Resilience Portal: A decision support system for Myanmar



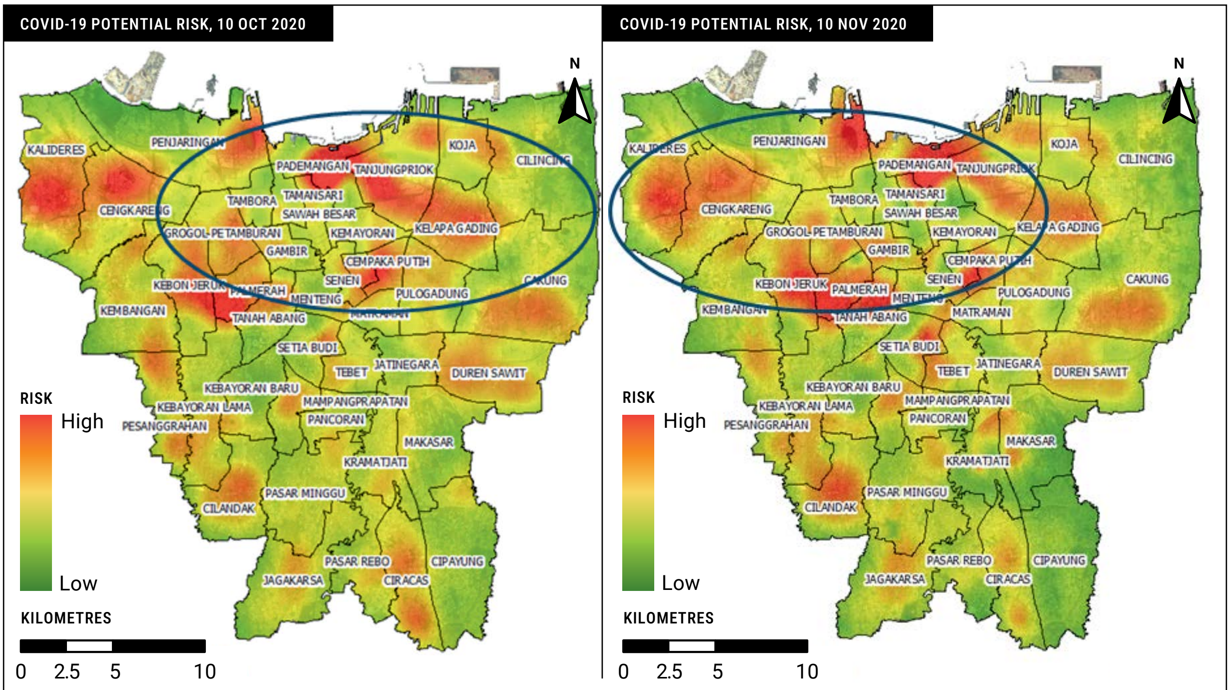
Source: ESCAP, "Risk and Resilience Portal". Available at rrp.unescap.org.

During the COVID-19 outbreak, Indonesia experienced many floods and landslides and had to manage a number of cascading risks. The Government implemented targeted interventions in specific zones based on dynamic risk assessments (Figure 5-3).[84] The resulting cluster-containment response strategies yielded positive results and are also helping other countries restrict the transmission of COVID-19, especially within vulnerable communities.[85] The Indonesian National Board for Disaster Management (BNPB) has been coordinating and managing COVID-19, integrating disaster and COVID-19 information for relevant use, and using information from OneData Indonesia.

84 Fajar Yulianto, "How Space Technology Applications Contributed to Combating COVID-19: Development of LAPAN Hub COVID-19", presentation at the Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific (UN-GGIM-AP) Meeting, 2020.

85 Sanjay Srivastava, "Outpacing COVID-19: Key innovations prompt early warning for early actions", blog, 21 April 2020. Available at https://www.unescap.org/blog/outpacing-covid-19-key-innovations-prompt-early-warning-early-actions.

FIGURE 5-3 Mapping the potential risk of COVID-19 spread in Jakarta, Indonesia



Source: Fajar Yulianto, LAPAN, UNGGIM Asia-Pacific Meeting, ESCAP 2020.
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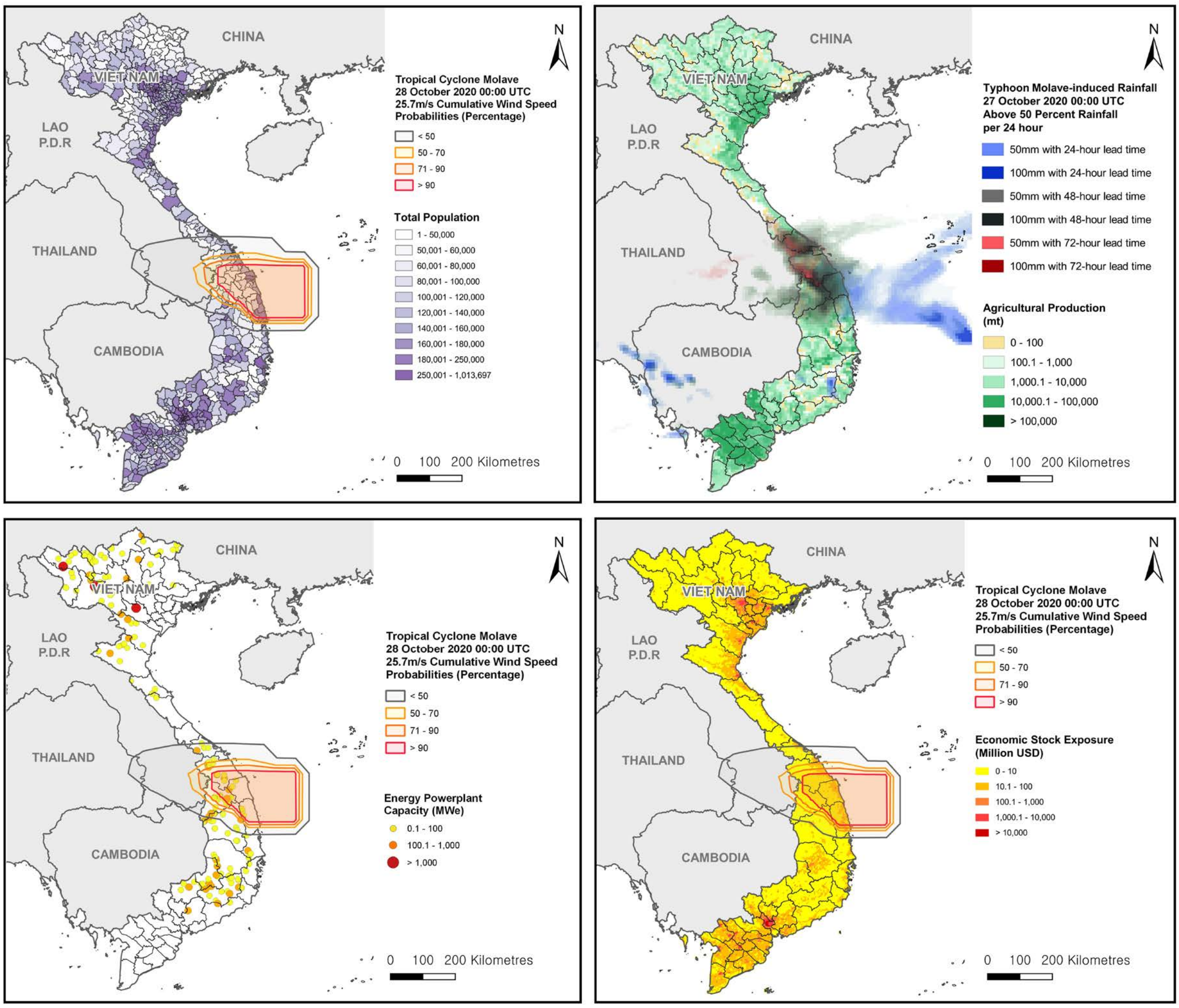
Impact-based forecasting

Well-functioning end-to-end early warning systems can significantly reduce disaster risks. Especially, **if the early warning information contains potential impacts of biological or other natural hazards, it can support various stakeholders to make appropriate decisions and take early action.** Moving from broadcasting 'what the weather will be' to 'what the weather will do' by combining hazard information with exposure and vulnerability data, impact-based forecasting can provide easy-to-understand customized information for critical sectors, such as disaster risk management, agriculture, energy, health, and water resources management.

To promote impact-based forecasting in the region, ESCAP has developed a methodology to operationalize such forecasting for extreme events and slow-onset disasters. Specifically, a training manual for operationalizing impact-based forecasting and warning services was created with demonstrative cases, including for Typhoon Molave that hit Viet Nam in October 2020 (Figure 5-4). ESCAP also organized the Joint Workshop on Strengthening Multi-Hazard Early Warning Systems and Early Actions in South-East Asia in February 2020, in partnership with WMO, FAO, RIMES, and Thailand Meteorological Department.[86] ESCAP also contributed to impact-based forecasting and warning services workshops organized by WMO for Viet Nam, in December 2020, and for Thailand in January 2021.

86 United Nations Economic and Social Commission for Asia and the Pacific, "Joint Workshop on Strengthening Multi-Hazard Early Warning Systems and Early Actions in South-East Asia", workshop, 18–20 February 2020a. Available at https://unescap.org/events/joint-workshop-strengthening-multi-hazard-early-warning-systems-and-early-actions-south-east.

FIGURE 5-4 **Exposure of population, agricultural production, energy powerplants, and economic stock in Viet Nam to Typhoon Molave, October 2020**



Sources: ESCAP, based on Viet Nam National Meteorological and Hydrological Administration (VNMHA) Typhoon induced Rainfall, 27 October 2020; National Oceanic and Atmospheric Administration-Regional and Mesoscale Meteorological Branch (NOAA-RAM MB) Typhoon Wind, 28 October 2020; World Pop 2020 Population Estimates; FAO Global Spatially-disaggregated Crop Production Statistics Data of 2020 (MapSPAM) v2r0 2020; ESCAP Asia-Pacific Energy Portal, 2018; Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015; and UN Geospatial.

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South-East Asian countries are already moving towards impact-based forecasting. For example, in the Philippines, impact-based forecasting has been applied to issue warnings from risk assessments considering hazard, exposure, and vulnerability. A risk matrix is used to communicate the risk, which guides actions to be taken according to respective risk levels (Figure 5-5).

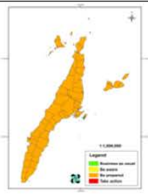
FIGURE 5-5 Communication of risk – impact-based forecasting in the Philippines

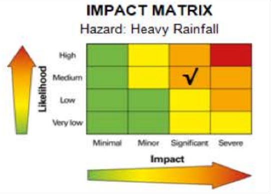
Republic of the Philippines
DEPARTMENT OF SCIENCE AND TECHNOLOGY
Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)

IMPACT-BASED WARNING NO. 1

MEDIUM LIKELIHOOD OF SIGNIFICANT IMPACTS DUE TO HEAVY RAINFALL TO OCCUR IN THE PROVINCE OF CEBU WITHIN THE NEXT 24 HOURS

Weather System: Tropical Storm Auring
Issued at 02:00PM, 21 February 2021
Valid until 02:00PM, 22 February 2021





Event description:

Tropical Storm (TS) "Auring" maintains its strength while over the Philippine Sea. At 10:00AM today, the center of TS Auring was estimated based on all available data at 335 km east of Hinatuan, Surigao Del Sur. It is moving almost stationary with maximum sustained winds of up to 65kph near the center and gustiness of up to 80kph.

Medium likelihood of heavy rainfall over the Province of Cebu this afternoon until evening while moderate rainfall is less likely tomorrow morning.

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Tel. No.: 8284-08-00
Website: http://bagong.pagasa.dost.gov.ph

What to expect:

Highlights of Severe Impacts Based on Impact Table

Life	• Few Injuries
Education	• One Day Suspension Of Classes • Pre-Schools To High Schools Class Suspension • High-School And College
Power	• Isolated Cases Of Electrocution • Localized Damage To Powerlines • 3 To 4 Hrs Power Interruption • Brownout In Some Areas
Structures & Infrastructures	• Major Damage To Dwellings And Infrastructure • Some Bridges Are Flooded • Homes Made Of Light Materials Will Be Affected
Communication	• Temporary Interruption Of Communications (Mobile Phones, Internet, Tv And Radio) • Possible Slow Connectivity Of Network Signals
Water Utility	• Power Outage And Water Interruption • Discoloration Is Visible
Transportation	• Not Passable To Both Light And Medium Vehicle • Slow Moving Of Traffic Due To Some Areas Not Passable. • Advised For Road Closures • Some Roads Are Close Due To Significant Flooding • Stranded Commuters
Health	• Short Term Confinement Due To Injuries And Diseases • High Possibility Of Water And Food Contamination • Increase Of Water Borne Diseases
Agriculture	• Damages To Crops (Flowers And Vegetables) • Livestock And Number Of Crops Affected
Basic Services	• Suspension Of Work Except For Agencies Delivering Basic Services

The public and the Disaster Risk Reduction and Management Office (DRRMO) concerned are advised to take appropriate actions and watch for the next Impact-Based Warning to be issued at 02:00 PM tomorrow unless significant changes occur.

Prepared by: PAGASA – WCSSP-SeA Team

__Disclaimer:__ This IBF Warning issuance is for research and development purpose only. Content of which should not be used for public consumption nor for any decision making purposes by local disaster managers. Should there significant changes of the weather system, this issuance will be updated prior to the regular issuance time.

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GREEN	**NO SEVERE WEATHER EXPECTED**
YELLOW	**BE AWARE.** There is a moderate risk of severe or a low risk of extreme weather occurring. *Remain alert and ensure you access the latest weather forecast.*
AMBER	**BE PREPARED.** There is a high risk of severe or a moderate risk of extreme weather occurring. *Remain vigilant and ensure you access the latest weather forecast. Take precautions where possible.*
RED	**TAKE ACTION.** There is a high risk of an extreme weather event occurring. *Remain extra vigilant and ensure you access the latest weather forecast. Follow orders and any advice given by authorities under all circumstances and be prepared for extraordinary measures.*

Source: ESCAP/WMO Typhoon Committee - 16th Integrated Workshop: Strengthening Impact-based Forecasting for Improving the Capacity of Typhoon-related Disaster Risk Reduction. Presentation delivered by PAGASA at the workshop. 2–3 December 2021. Available at https://www.unescap.org/events/2021/escapwmo-typhoon-committee-16th-integrated-workshop-strengthening-impact-based.

Innovation ecosystems

Building back better from COVID-19 will require innovations across sectors, as well as in the overall process of planning for disasters.[87] Success will also depend on strategic foresight and policy coherence to mitigate trade-offs between competing priorities and to ensure that the complete package is cost-effective and risk-informed.[88] For instance, to strengthen the working forces on science and technology, Malaysia launched the National Policy on Science, Technology and Innovation (DSTIN) 2021–2030, designed to transform the country from a tech user to a tech developer. The Ministry of Science, Technology and Innovation (MOSTI) has also introduced a 10-10 Malaysia Science, Technology, Innovation and Economy (STEI) framework that encompasses ten technology drivers on ten socioeconomic drivers to enable socioeconomic transformation and economic growth.[89, 90] It would also allow an agile national innovation ecosystem.

BOX 5-1 Web-based platform to support nationwide COVID-19 vaccination drive in Viet Nam

In July 2021, a telecom group Viettel launched a COVID-19 immunization management platform to facilitate mass inoculation in Viet Nam. The nation-wide COVID-19 inoculation drive spread across 63 cities and provinces with 19,500 vaccination centres.

The platform comprises four key systems:

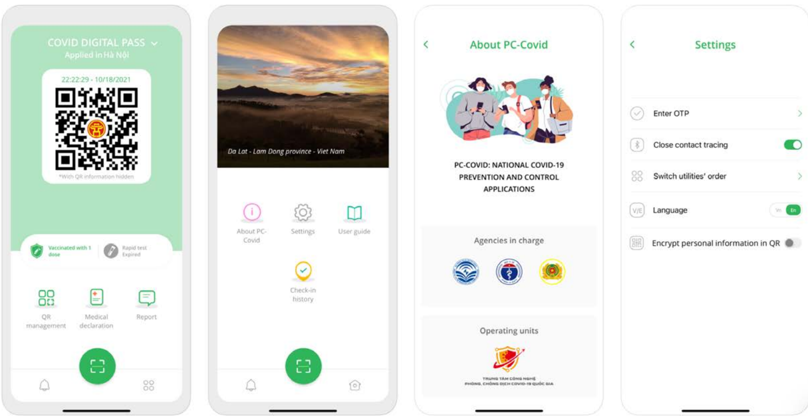
1 An e-health record application,

2 A portal for COVID-19 immunization information,

3 A system supporting national vaccination, and

4 An MCC centre (Mennonite Central Committee).

The immunization information portal and e-health record application enables people to register for vaccinations and track their records. The objectives of this platform are to support speeding up the nationwide vaccination campaign and increase its safety, effectiveness and transparency in support of the management of the COVID-19 vaccination drive in Viet Nam.



Source: "National immunisation management platform enables online registration for COVID-19 vaccination", *Viet Nam News*, 10 July 2021. Available at https://en.vietnamplus.vn/national-immunisation-management-platform-enables-online-registration-for-covid19-vaccination/204459.vnp; and PC-COVID Viet Nam. Available at Apple.com (Applications store).

87 Global Centre on Adaptation, "Adaptation Finance in the Context of Covid-19: The role of development finance in prompting a resilient recovery", January 2021. Available at https://gca.org/wp-content/uploads/2021/01/GCA-Adaption-in-Finance-Report.pdf.

88 Organisation for Economic Co-operation and Development, "Building a coherent response for a sustainable post-COVID-19 recovery", 23 November 2020. Available at https://read.oecd-ilibrary.org/view/?ref=376_376369-eayqu00bgf&title=Building-a-coherent-response-for-a-sustainable-post-COVID-19-recovery.

89 Ir Siti Hamisah Tapsir, "Collaboration and innovation to overcome COVID-19 challenges", International Science Council, 27 September 2021. Available at https://www.ingsa.org/ingsa-news/collaboration-and-innovation-to-overcome-covid-19-challenges-dr-ir-siti-hamisah-tapsir/.

90 Government of Malaysia, "National Policy on Science, Technology and Innovation (NPSTI)", MyGovernment, 2021b. Available at https://www.malaysia.gov.my/portal/content/30923.

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Pathways to Adaptation and Resilience in South-East Asia demonstrates how the South-East Asian subregion is being affected by various risk parameters, and where new hotspots of exposure and vulnerability to climate-induced, cascading multi-hazard scenarios are being created. Moving forward, ESCAP recommends that South-East Asia implements customized adaptation and resilience pathways with emphasis on risk-informed development policies and investments, technological innovations and subregional cooperation approaches. These measures can accelerate the progress of countries in achieving the Sustainable Development Goals and the targets of the Sendai Framework for Disaster Risk Reduction.